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# The Modern Single-Phase Railway Motor.

## SOME OF ITS CHARACTERISTICS.

*By ANDREW STEWART, A.M.I.E.E.*

RAILWAY electrification has been discussed from so many standpoints that it is difficult, if not altogether impossible, to say much that is new on the subject. This is not the case, however, with the single-phase motor, as, while there have been several valuable contributions to the theory of the motor there has been a dearth of information regarding its general construction and performance. The average engineer is keenly interested in the latter, while the former interests a very limited circle, and is generally so abstruse that the busy professional man has neither the time nor the inclination to follow the mathematical efforts of those who mould and direct the progressive tendencies of the industry.

When railway electrification first came within the purview of the engineer, experience was limited to electric tramway work, and knowledge was bounded by the trolley wheel and wire on one hand, and 500 volts and the rotary converter on the other.

The electrification of the Baltimore tunnel impressed engineers for the first time with the serious limitations of direct current, for here we had an overhead structure for conveying current to the locomotives which resembled the work of a bridge builder, just as the overhead construction in earlier electric tramways looked like the work of a telephone linesman.

This early railway electrification at once convinced the railway engineer that the conveyance of anything from 1,000 to 2,000 h.p. to a moving train must be effected by higher pressures, if anything like reasonable economy in construction was to be achieved, and if a structure, not unlike an overhead railway, extending along the entire length of the line, were to be avoided. Polyphase systems had been brought to a high pitch of perfection, and for a time

it looked as if this system would supersede the direct current system for heavy work, for notwithstanding the fact that two overhead wires were necessary, these could, by reason of the high pressures possible, be but little more than the section of an ordinary tramway trolley wire, while the regenerative properties of the induction motor promised economies hitherto merely suspected. These expectations were fully substantiated by the results achieved on several mountain railways in Italy and Switzerland, as well as on a small section of the Italian State Railways.

Somehow the polyphase system did not catch on in the United States of America, where engineers, despite their boasted adaptability and enterprise, can be as conservative as Englishmen, and there are practically no examples of this system in the United States. There is, or was, one such system in Canada, the equipment having been carried out by Messrs. Bruce Peebles, Ltd., of Edinburgh, but this line subsequently came under the control of American capitalists, and a direct current equipment was substituted, though there is no evidence that the polyphase system was other than satisfactory.

European engineers were, however, working towards the perfection of a still more simple system, viz., one employing single-phase motors. Such motors had long held a reputation for muleish characteristics; for instance, if loaded beyond their rated load they would sometimes stop dead; others refused to start with more than a fraction of their full load, so that altogether the outlook was not of a very hopeful nature. Moreover, the polyphase alternating-current motor was the direct result of the unsatisfactory performance of the single-phase alternating-current motor; indeed, it is safe to assert that, but for the idiosyncrasies of the earlier single-phase motors, we should never have heard of polyphase motors at all.

The ultimate end of this work on single-phase railway motors was the single-phase series motor, which is a reversion to a type of machine tried and abandoned some twenty years before. Indeed, never was the atavistic freaks of biology more nearly paralleled in industrial history than when the single-phase series motor, almost the first type of electric motor, was resurrected and made to drive the railway trains of to day.

It was early recognised that the simple series direct-current motor, if fitted with laminated instead of a solid field magnet, and with a moderate amount of field winding, would be fairly satisfactory as a single-phase alternating-current motor. The difficulty was that such motors were not satisfactory at the high frequencies then employed—viz., 80 to 100 cycles per second. As these were standard periodicities, and moreover, any reduction apparently raised the cost of generating and transforming apparatus very considerably, while lighting and not power was the chief business of electric supply authorities, there was really no reason for reducing the periodicity of the supply system to a figure that would make the series alternating-current motor practicable. It was not until within the last twelve years that the demand for electric power made it worth catering for the power user, and then the elementary series alternating-current motor had been superseded by rotary field or induction type motors, the result of the labours of Ferraris and Tesla.

It must be obvious that to seriously threaten the supremacy of the steam locomotive, electric traction must first of all make no large demand upon the financial resources of our great railway companies. Capital expenditure is unlikely to be undertaken unless there is ample evidence to show that this additional capital will at least be as remunerative as that already sunk in the undertaking. The direct current system installed on British lines, with its heavy outlay on transmission and distributing apparatus, especially substations with not only their capital, but labour charges, does not encourage engineers to instal it on main lines. For suburban work, where the collateral

advantages, such as rapid acceleration and more frequent service, enable the line to *increase* its earnings by attracting traffic which would otherwise use other means of conveyance, this extra capital is not so serious as, in addition to a reduction in the locomotive expenses, there is an increase in the traffic receipts. With main line traffic no increase under the latter heading can be looked for, as there is no reason to suppose that any electrification scheme would increase the number of people who travel between London and Birmingham, or Newcastle and Edinburgh.

The financial reasons for the adoption of a simpler system than the direct-current method of propulsion are obvious, and these are no less important than the engineering considerations already indicated.

Another consideration is that, owing to the electrification of several important suburban lines, such as those in the vicinity of London, Newcastle and Liverpool, any system adopted on main lines should, if possible, be one that permits of main line trains being run over these electrified lines which, if they are not great in extent, yet handle a not inconsiderable volume of traffic, and a change of locomotive power might at least be inconvenient.

Both polyphase and single-phase motors permit of such modifications in design as will enable them to work with fair efficiency on direct-current circuits. The single-phase motor is, however, more adaptable in this respect, as to adapt a polyphase motor to the dual service involves the sacrifice of some points when operating on alternating-current circuits. Moreover, the single-phase motor operates from one line wire in any case, while an additional trolley or other collecting device, and separate car or locomotive wiring is necessary where the polyphase motor is adapted to two "distinct" supplies.

The relative merits of the three-phase, single-phase, and direct-current systems have been investigated by the experts employed by several railway companies. From a report submitted to the directors of a small railway from Murnau to Ober-Ammergau—a line in the Bavarian Highlands—it would appear that single-phase has almost overwhelming advantages, and the figures bear out the argument used earlier as to the advantages of the system.

TABLE I. COMPARISON OF SYSTEMS OF ELECTRIC TRACTION.

| | Three-Phase. | Single-Phase. | Direct Current. |
|---|---|---|---|
| | Per cent. | Per cent. | Per cent. |
| Efficiency . | 66 | 71 | 62 |
| Capital cost | 1·16 | 1·0 | 1·25 |

According to this report the single-phase system is not only more efficient, but less costly. It must not be forgotten, however, that the report refers to a line fourteen miles in length, with stations approximately two miles apart, operating not more than sixteen trains per day at a maximum speed of twenty-four miles per hour. Moreover, the line is operated by water power, so that while useful as a guide under similar conditions, it is not necessarily an accurate indication of the relative merits under other conditions.

For instance, the single-phase equipment of a train weighs a little more and is more expensive than is a three-phase or direct-current equipment; but, on the other hand, the sub-station losses are less than with a direct current equipment, so also is the capital cost of the sub-stations. The three-phase and the single-phase systems are almost directly comparable so far as distribution losses are concerned; both are necessarily low, as the sub-stations do not contain moving machinery; they are therefore cheap to construct and maintain.

The overhead line work of a single-phase system is cheaper than for a three-phase system, not on account of any saving in copper, as in this respect the three-phase system is the most economical for a given line pressure, but because only one overhead line wire need be erected instead of two, thus cheapening the cost, especially the fittings and labour.

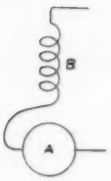



FIG. 1.

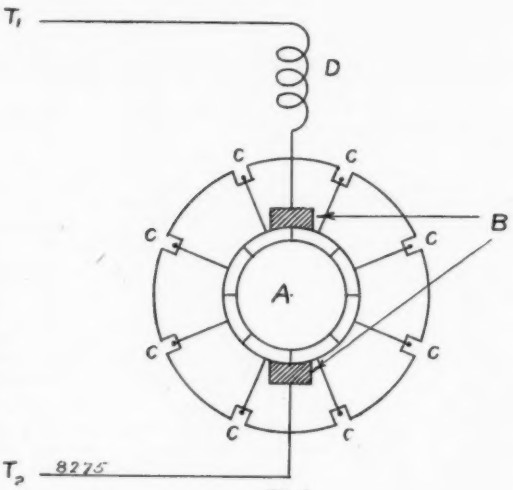



FIG 2.

The single-phase railway motors of the present day may be divided into three groups: series motors, compensated series motors, and repulsion motors. The plain series motor was the subject of investigation by Mr. B. G. Lamme, of Pittsburg, and Mr. Finzi, of Milan; later Messrs. G. Winter and F. Eichberg worked on a modification, viz., the compensated repulsion motor.

The plain series motor is shown diagrammatically (Fig. 1), where *A* is the armature and *B* the field coil. It will be obvious that the connections are identical with the series direct-current motor, the only difference being, as already indicated, that the field system is laminated.

The disadvantage of such a motor is that it is liable to spark at the commutator, as the self-induction of the armature coil when under commutation is considerable. The obvious methods of overcoming the difficulty are by increasing the number of commutator segments and having only one turn of armature wire per segment.

To still further improve the commutation of the series motor compensating coils have been fitted, the effect of which is to reduce the self-induction of the coils under commutation and so reduce the sparking at the commutator.

It may be explained for the benefit of mechanical engineers that the phenomena of self-induction is to some extent analogous to inertia in mechanics, as it represents the tendency of the current in an electric circuit to oppose any change in its direction. For instance, assume that the commutator *A*, Fig. 2, consists of a number of segments, and that each is connected to two turns of wire in the armature coils *C*. As each segment of the commutator passes under the fixed brushes *B*, which make connection to the field *D* and line wires $T^1$ $T^2$, the current in the coil connected to the segment passing under the brush is reversed. As no less than 100, and frequently a greater number of segments pass under the brush every second, it will be seen that the problem of commutation is an important one, especially as each coil when under commutation, *i.e.*, passing under the brush, resists the change in the direction of the electric current.

It is just as if each coil connected to the commutator segments were a small flywheel running at a certain speed, and were stopped and speeded up in the reverse direction when passing under the brush; that is, in about the $\frac{1}{100}$ part of a second. It will be obvious that the retardation and acceleration of these numerous small wheels would have to be done with great rapidity.

*(To be continued.)*

# Testing a Centrifugal Fan.

*By C. L. BROWNE.*

IN spite of its rapid growth in public favour, the principles involved in the operation of a centrifugal fan do not appear to have received the attention they deserve from the general engineering public, who are thus left more or less in the hands of the makers, and the present keen American competition in the British fan market does not tend to influence manufacturers of centrifugal fans in favour of underestimating the capacity of their machines.

Modified designs are from time to time being put upon the market, and in spite of published tests, the somewhat extravagant claims made are not always borne out in practice.

The chief difference, shall it be said, of opinion seems to arise over the efficiencies that may be reasonably claimed for a centrifugal fan, and the difficulty is very greatly augmented by the varied conditions under which the fan is put to work.

A fan that has given excellent results when run on the test plate has, owing to some slight difference in supposedly similar working conditions, made a very poor showing when put on permanent duty.

The writer proposes to briefly indicate a method of arriving at the volumetric, manometric, and mechanical efficiencies of centrifugal fans by which the relative value of any fan may be judged.

It will be impossible to avoid a brief reference to the elementary mathematics of the subject, but the formulæ used will be divested of any extreme complications such as would be necessitated by absolute accuracy, which would be out of place when dealing with the performance of centrifugal fans, as will be later made evident. Before going further into the subject it may be as well to briefly recall several facts in connection with the flow of liquids.

If a liquid be contained in a vessel (Fig. 1) with its free horizontal surface maintained at a height $H$ in feet above any assumed datum level, and if the liquid at $A$ under a pressure $P$ lbs. per sq. ft., and a height $h$, above the given level, has a velocity $v$ in feet per second, and a density $D$ lbs. per cub. ft. Then—

$$h + \frac{P}{D} + \frac{v^2}{2g} = H \qquad (1)$$

Thus the ft. lbs. of potential energy $H$ per lb. appear at $A$ in three different forms, namely: remaining potential energy $h$, pressure energy $\frac{P}{D}$ and kinetic energy $\frac{v^2}{2g}$. Hence the liquid under pressure $P$, at a velocity $v$, and at a height $h$, has a pressure head $\frac{P}{D}$, a velocity head $\frac{v^2}{2g}$, and an actual head $h$.

If, however, the liquid were to issue freely into the atmosphere under the head $H$, this total head would be available for producing flow, then—

$$H = \frac{v^2}{2g}, \text{ or } v = \sqrt{2gH} \qquad (2)$$

As at the ordinary pressures found in fan practice the work required for the compression of the air and the work given out by its re-expansion are negligible, especially if the mean volume of the air handled be taken, formula (1) may be applied to air, thus assuming its behaviour to be similiar to that of a liquid in this respect. Although the density of the air decreases in geometric ratio as the distance from the earth increases, for the purposes of calculation the practical equivalent of such a column may be determined by assuming the air to be of uniform density throughout, and the column of such a height as to produce the same effective pressure per unit of area.

Although in the American fan trade it is usual to measure air pressures in ounces per sq. in., the British practice is to express these pressures in inches of water, as

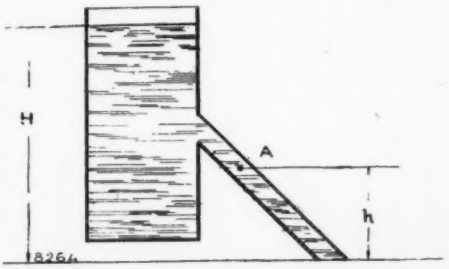



FIG. 1.

TABLE I.—PRESSURES IN INCHES OF WATER AND CORRESPONDING VELOCITIES OF EFFLUX IN FEET PER MINUTE AT VARIOUS TEMPERATURES IN DEGREES F.

| Pressure in Inches of Water. | Air Velocities. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 50° | 62° | 100° | 200° | 300° | 350° | 400° | 450° | 500° | 550° | 600° | 650° | 700° | 750° | 800° | 900° | 1,000° |
| ·25 | 1,980 | 2,000 | 2,075 | 2,250 | 2,420 | 2,500 | 2,860 | 2,642 | 2.720 | 2,789 | 2,860 | 2,925 | 2,989 | 3,060 | 3,114 | 3,230 | 3,350 |
| ·5 | 2,800 | 2,830 | 2,935 | 3,533 | 3,420 | 3,535 | 3,635 | 3·740 | 3,840 | 3.940 | 4,040 | 4,130 | 4,240 | 4,330 | 4,400 | 4,560 | 4,735 |
| ·75 | 3,430 | 3,460 | 3,595 | 3,892 | 4,190 | 4,330 | 4·450 | 4,575 | 4,700 | 4,825 | 4.940 | 5.060 | 5,170 | 5,300 | 5,380 | 5.590 | 5,800 |
| 1 | 3,960 | 4.000 | 4,150 | 4,500 | 4,840 | 5,000 | 5,140 | 5.292 | 5,430 | 5,575 | 5,710 | 5,860 | 5,975 | 6,125 | 6,225 | 6,460 | 6,700 |
| 1·25 | 4,425 | 4,460 | 4,640 | 5,025 | 5,390 | 5,570 | 5,740 | 5,900 | 6,050 | 6,230 | 6,380 | 6,530 | 6,665 | 6,845 | 6,940 | 7,210 | 7,480 |
| 1·5 | 4,850 | 4.900 | 5,075 | 5,520 | 5.910 | 6,110 | 6,280 | 6,470 | 6,650 | 6,820 | 6,990 | 7.160 | 7,300 | 7.509 | 7,610 | 7.9c0 | 8,190 |
| 1·75 | 5,240 | 5,280 | 5,480 | 5,940 | 6,390 | 6,600 | 6,790 | 6,980 | 7,170 | 7.360 | 7.540 | 7.740 | 7.890 | 8,100 | 8,220 | 8.540 | 8,860 |
| 2 | 5,590 | 5,650 | 5.860 | 6,350 | 6,840 | 7,060 | 7.250 | 7,470 | 7,870 | 7,870 | 8,060 | 8,250 | 8,430 | 8,650 | 8,800 | 9,120 | 9,460 |
| 2·25 | 5.940 | 5 990 | 6,210 | 6,740 | 7,240 | 7,480 | 7,690 | 7,910 | 8,130 | 8,340 | 8,550 | 8,760 | 8,940 | 9,160 | 9.310 | 9,660 | 10,040 |
| 2·5 | 6.250 | 6,310 | 6.550 | 7,100 | 7,640 | 7,880 | 8,110 | 8,350 | 8,560 | 8,790 | 9,010 | 9,240 | 9,425 | 9.660 | 9,825 | 10,210 | 10,590 |
| 2·75 | 6,550 | 6,625 | 6,870 | 7,450 | 8,010 | 8,280 | 8,500 | 8,760 | 8,980 | 9,230 | 9,450 | 9.699 | 9,880 | 10,140 | 10,300 | 10,700 | 11,100 |
| 3 | 6,840 | 6 900 | 7,160 | 7,775 | 8,350 | 8,640 | 8,870 | 9,150 | 9,380 | 9,630 | 9.879 | 10,100 | 10,320 | 10,590 | 10,760 | 11,170 | 11,580 |
| 3·25 | 7,110 | 7,190 | 7.460 | 8.074 | 8.670 | 8,990 | 9,240 | 9,510 | 9,760 | 10,020 | 10,280 | 10,510 | 10,740 | 11,000 | 11,200 | 11,610 | 12,050 |
| 3·5 | 7.390 | 7.460 | 7,740 | 8,373 | 9,010 | 9.330 | 9.590 | 9,860 | 10,130 | 10,400 | 10,670 | 10,905 | 11,150 | 11,410 | 11,600 | 12,070 | 12,500 |
| 3·75 | 7,650 | 7.750 | 8,000 | 1,672 | 9,330 | 9,660 | 9,930 | 10,220 | 10.500 | 10,780 | 11,040 | 11,295 | 11.530 | 11,810 | 12,020 | 12,590 | 12.950 |
| 4 | 7.890 | 7.960 | 8.270 | 8 970 | 9,650 | 9,960 | 10,240 | 10,550 | 10.820 | 11,110 | 11,400 | 11,670 | 11.910 | 12,210 | 12,400 | 12 890 | 13,350 |
| 4·25 | 8,130 | 8,200 | 8,510 | 9,233 | 9,940 | 10,280 | 10,560 | 10,880 | 11,180 | 11.476 | 11.740 | 12,020 | 12,280 | 12,590 | 12,800 | 13.290 | 13,780 |
| 4·5 | 8.360 | 8.430 | 8,760 | 9,496 | 10,220 | 10,580 | 10,880 | 11,290 | 11.500 | 11,790 | 12.080 | 12,360 | 12,620 | 12,940 | 13.150 | 13,670 | 14,180 |
| 4·75 | 8,600 | 8,670 | 9,200 | 9,758 | 10,500 | 10,870 | 11.180 | 11,500 | 11,800 | 12,100 | 12,410 | 12,700 | 12 980 | 13.300 | 13.500 | 14,050 | 14,550 |
| 5 | 8.820 | 8.900 | 9,240 | 10,020 | 10,780 | 11,130 | 11,450 | 11,780 | 12,080 | 12,410 | 12,720 | 13,020 | 13,280 | 13,630 | 13,850 | 14,390 | 14,910 |
| 5·25 | 9.030 | 9.110 | 9,460 | 10,250 | 11,040 | 11,400 | 11,720 | 12,050 | 12,390 | 12,710 | 13,040 | 13.340 | 13,62c | 13.980 | 14.190 | 14,750 | 15,280 |
| 5·5 | 9,230 | 9,330 | 9.670 | 10,590 | 11,290 | 11,680 | 11,990 | 12.340 | 12,680 | 13,010 | 13,330 | 13,650 | 13,930 | 14,300 | 14 540 | 15,100 | 15,630 |
| 5·75 | 9.430 | 9.540 | 9,880 | 10,830 | 11,540 | 11.940 | 12,260 | 12,620 | 12,970 | 13,300 | 13,630 | 13,950 | 14,250 | 14.600 | 14 850 | 15 420 | 15.980 |
| 6 | 9,640 | 9,750 | 10,100 | 10,970 | 11,790 | 12.190 | 12.510 | 12,890 | 13 220 | 13.580 | 13,910 | 14,230 | 14.530 | 14,900 | 15,170 | 15,740 | 16,310 |
| 6·25 | 9,830 | 9.940 | 10,300 | 11,150 | 12,020 | 12,440 | 12 770 | 13.160 | 13,500 | 13,850 | 14,200 | 14.530 | 14,840 | 15,220 | 15,480 | 16,080 | 16,650 |
| 6·5 | 10,020 | 10,130 | 10,500 | 11,330 | 12,250 | 12,680 | 13 020 | 13.400 | 13,770 | 14.120 | 14,490 | 14,830 | 15,140 | 15.520 | 15.790 | 16,390 | 16,990 |
| 6·75 | 10,210 | 10,310 | 10,700 | 11 520 | 12,480 | 12,910 | 13,270 | 13,660 | 14,020 | 14,390 | 14.780 | 15,100 | 15,410 | 15,820 | 16,080 | 16,700 | 17,300 |
| 7 | 10,400 | 10,500 | 10,900 | 11,700 | 12,700 | 13,130 | 13,510 | 13 900 | 14,270 | 14,630 | 15,010 | 15,370 | 15,690 | 16,100 | 16,350 | 16,880 | 17,600 |
| 7·25 | 10,580 | 10,680 | 11,080 | 11.900 | 12.920 | 13,360 | 13.750 | 14,140 | 14,510 | 14,890 | 15,270 | 15,630 | 15,980 | 16,360 | 16,610 | 17.290 | 17,900 |
| 7·5 | 10,760 | 10,860 | 11,270 | 12,100 | 13,140 | 13,600 | 13.990 | 14,380 | 14,760 | 15,150 | 15.520 | 15.900 | 16,240 | 16,640 | 16 900 | 17,580 | 18,200 |
| 7·75 | 10.940 | 11,030 | 11,450 | 12,300 | 13.360 | 13,810 | 14,200 | 14.610 | 15,000 | 15,400 | 15.780 | 16,170 | 16,500 | 16,910 | 17.190 | 17,850 | 18,500 |
| 8 | 11,110 | 11,210 | 11,630 | 12,500 | 13.580 | 14,030 | 14,410 | 14.830 | 15,230 | 15,620 | 16,030 | 16,400 | 16,760 | 17,180 | 17.470 | 18.100 | 18.790 |
| 8·25 | 11,280 | 11,380 | 11,800 | 12,720 | 13,790 | 14,240 | 14,620 | 15,060 | 15,470 | 15.870 | 16,260 | 16,650 | 17,000 | 17,440 | 17.700 | 18,400 | |
| 8·5 | 11,450 | 11,560 | 11,980 | 12,940 | 13,990 | 14,470 | 14,850 | 15,290 | 15.700 | 16,100 | 16,500 | 16,910 | 17,270 | 17,700 | 17.990 | 18,700 | |
| 8·75 | 11,610 | 11,730 | 12,160 | 13,160 | 14,190 | 14,680 | 15.080 | 15.500 | 15.920 | 16.340 | 16.740 | 17,150 | 17.500 | 17.950 | 18 230 | 18 950 | |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 11,780 | 11,900 | 12,330 | 13,380 | 14 390 | 14,890 | 15,290 | 15,700 | 16,130 | 16,560 | 16,980 | 17,390 | 17,750 | 18,190 | 18,490 | 19,200 |
| 9 25 | 11,910 | 12,050 | 12 500 | 13,550 | 14,570 | 15,090 | 15,490 | 15,910 | 16,340 | 16,720 | 17,200 | 17,610 | 17,990 | 18,430 | 18,730 | |
| 9'5 | 12,030 | 12,200 | 12,660 | 13,730 | 14,750 | 15,280 | 15,690 | 16,130 | 16,570 | 17,000 | 17,410 | 17,840 | 18,230 | 18,690 | 18,990 | |
| 9'75 | 12,150 | 12,350 | 12,830 | 13,910 | 14 930 | 15,460 | 15,890 | 16,340 | 16,780 | 17,210 | 17,640 | 18,080 | 18,470 | 18,930 | 19,220 | |
| 10 | 12,280 | 12,500 | 12,990 | 14,080 | 15,110 | 15,630 | 16,086 | 16,530 | 16,980 | 17,410 | 17,850 | 18,290 | 18,690 | 19,140 | 19,450 | |
| 10'25 | 12,460 | 12,650 | 13,140 | 14,230 | 15,300 | 15,810 | 16,270 | 16,730 | 17,190 | 17,630 | 18,070 | 18,500 | 18,900 | 19,390 | | |
| 10'5 | 12,630 | 12,800 | 13,300 | 14,420 | 15,490 | 16,000 | 16,450 | 16,920 | 17,400 | 17,850 | 18,300 | 18,710 | 19,120 | 19,600 | | |
| 10 75 | 12,800 | 12,950 | 13,450 | 14,580 | 15,670 | 16,200 | 16,650 | 17,130 | 17,600 | 18,070 | 18,500 | 18,910 | 19,340 | 19,840 | | |
| 11 | 12,980 | 13 100 | 13,600 | 14,750 | 15,850 | 16,380 | 16,830 | 17,310 | 17,800 | 18,250 | 18,700 | 19,150 | 19,520 | 20,050 | | |
| 11'25 | 13,130 | 13,250 | 13,750 | 14,910 | 16,330 | 16,570 | 17,010 | 17,500 | 17,990 | 18,450 | 18,900 | 19,350 | 19 740 | | | |
| 11'5 | 13,270 | 13,390 | 13,900 | 15,080 | 16,210 | 16,740 | 17,200 | 17,700 | 18,180 | 18,660 | 19 110 | 19,570 | 19,980 | | | |
| 11'75 | 13,410 | 13,540 | 14,050 | 15,240 | 16,380 | 16,930 | 17,390 | 17,900 | 18,380 | 18,870 | 19,320 | 19,790 | 20,200 | | | |
| 12 | 13,560 | 13,680 | 14,200 | 15,400 | 16,550 | 17,100 | 17,570 | 18,080 | 18,570 | 19,050 | 19,510 | 19,980 | 20,400 | | | |
| 12'25 | 13,690 | 13,810 | 14,340 | 15,550 | 16,710 | 17,270 | 17,740 | 18,270 | 18,750 | 19,230 | 19,700 | 20,200 | | | | |
| 12'5 | 13,820 | 13,950 | 14,470 | 15,700 | 16,870 | 17,440 | 17,910 | 18,420 | 18,930 | 19,420 | 19,900 | 20,400 | | | | |
| 12'75 | 13,950 | 14,080 | 14,600 | 15,850 | 17,030 | 17,610 | 18,100 | 18,630 | 19,120 | 19,620 | 20,100 | 20,600 | | | | |
| 13 | 14,080 | 14,210 | 14,740 | 16,000 | 17,180 | 17,710 | 18,250 | 18,810 | 19,290 | 19,800 | 20,290 | 20,790 | | | | |
| 13'25 | 14,210 | 14,340 | 14,880 | 16,150 | 17,340 | 17,950 | 18,410 | 18,980 | 19,480 | 19,990 | 20,480 | | | | | |
| 13'5 | 14,340 | 14,480 | 15,020 | 16,300 | 17,500 | 18,120 | 18,580 | 19,140 | 19,650 | 20,180 | 20,680 | | | | | |
| 13'75 | 14,470 | 14,610 | 15,160 | 16,450 | 17,660 | 18,280 | 18,770 | 19,310 | 19,820 | 20,370 | 20,880 | | | | | |
| 14 | 14,600 | 14,740 | 15,300 | 16,600 | 17,820 | 18,450 | 18,910 | 19,480 | 19,900 | 20,550 | 21,080 | | | | | |
| 14'25 | 14,730 | 14,880 | 15,420 | 16,740 | 17,980 | 18,610 | 19,100 | 19,650 | 20,180 | 20,720 | | | | | | |
| 14'5 | 14,850 | 14,990 | 15,550 | 16,886 | 18,140 | 18,760 | 19,280 | 19,820 | 20,370 | 20,900 | | | | | | |
| 14'75 | 14,970 | 15,110 | 15,680 | 17,010 | 18,290 | 18,910 | 19,440 | 20,000 | 20,560 | 21,090 | | | | | | |
| 15 | 15,100 | 15,230 | 15,800 | 17,150 | 18,440 | 19,060 | 19,600 | 20,140 | 20,700 | 21,280 | | | | | | |
| 15'25 | 15,220 | 15,360 | 15,930 | 17,290 | 18,590 | 19,210 | 19,750 | 20,300 | 20,850 | | | | | | | |
| 15'5 | 15,340 | 15,480 | 16 070 | 17,430 | 18,740 | 19,360 | 19 900 | 20,460 | 21,010 | | | | | | | |
| 15 75 | 15,460 | 15,610 | 16,200 | 17,560 | 18 890 | 19,510 | 20,050 | 20,620 | 21,200 | | | | | | | |
| 16 | 15,580 | 15,780 | 16,340 | 17,700 | 19,030 | 19,660 | 20,190 | 20,780 | 21,360 | | | | | | | |
| 16'25 | 15,690 | 15,840 | 16,450 | 17,820 | 19,170 | 19,800 | 20,330 | 20,820 | | | | | | | | |
| 16'5 | 15,800 | 15,960 | 16,570 | 17,940 | 19 310 | 19,940 | 20,540 | 21,060 | | | | | | | | |
| 16'75 | 15,900 | 16,070 | 16,680 | 18,080 | 19,440 | 20,170 | 20,680 | | | | | | | | | |
| 17 | 16,010 | 16,180 | 16,790 | 18,200 | 19,570 | 20,200 | 20,780 | | | | | | | | | |
| 17'25 | 16,130 | 16,290 | 16,900 | 18,320 | 19,710 | 20,350 | | | | | | | | | | |
| 17'5 | 16,250 | 16,400 | 17,020 | 18,450 | 19,840 | 20,500 | | | | | | | | | | |
| 17'75 | 16,360 | 16,500 | 17,140 | 18,580 | 19,970 | 20,640 | | | | | | | | | | |
| 18 | 16,480 | 16,610 | 17,250 | 18,700 | 20,100 | 20,790 | | | | | | | | | | |
| 18'25 | 16,590 | 16,720 | 17,360 | 18,820 | 20,230 | | | | | | | | | | | |
| 18'5 | 16,690 | 16,840 | 17,470 | 18,950 | 20,860 | | | | | | | | | | | |
| 18'75 | 16,790 | 16,960 | 17,590 | 19,080 | 20,490 | | | | | | | | | | | |
| 19 | 16,900 | 17,070 | 17,770 | 19,200 | 20,620 | | | | | | | | | | | |
| 19'25 | 17,000 | 17,180 | 17,810 | 19,320 | | | | | | | | | | | | |
| 19'5 | 17,110 | 17,290 | 17,930 | 19,450 | | | | | | | | | | | | |
| 19'75 | 17,210 | 17,390 | 18,040 | 19,580 | | | | | | | | | | | | |
| 20 | 17,310 | 17,500 | 18,150 | 19,700 | | | | | | | | | | | | |

indicated by the balanced height of a column of that liquid in a water gauge.

The relation existing between pressure difference in inches of water and the equivalent head of air in feet is readily found as follows:—

Let $H$ = head of dry air in ft., and $h$ = the equivalent head of water in ins., then if $C$ = the weight of one cub. ft. of water, and $D$ the weight of one cub. ft. of air at the same temperature and pressure, then—

$$H = \frac{h \times c}{D \times 12} \qquad (3)$$

and if $V$ is the velocity of efflux in ft. per minute corresponding to a head of air equivalent to a column of water 1 in. in height, $h$ in this case being unity,—

$$\text{since } v = \sqrt{2gH}$$

$$V = 60\sqrt{2g\frac{h \times c}{12\,D}} \qquad (4)$$

which at 62° F. = 4,000 very approximately. Thus a velocity of 4,000 ft. per minute is said to be that corresponding to a water gauge reading of 1 in. at a temperature of 62° F.

It has already been shown that the velocity of efflux varies as the square root of the head producing it, and it will be evident that any decrease in the density of the air due to an increase of its temperature must, for the same pressure, increase the resulting velocity.

Hence as the height of the column of air required to produce a given water gauge varies directly as its absolute temperature, the corresponding velocity of the air will vary directly as the square root of its absolute temperature.

The above is an important consideration when fans are used for induced draft purposes, in which case the gas temperatures are seldom lower than 300° F., and in general are considerably higher. The relation of velocity to water gauge is also affected by the barometric and hygrometric condition of the air, but any variations due to these causes may generally be neglected in practical calculations made for the design of centrifugal fans.

With higher water gauges, however, such as obtain in cupola work, allowance should be made for the reduction in velocity due to the greater density of the air which accompanies the greater pressures employed.

The accompanying table has been calculated to give the velocities in feet per minute due to different pressures in inches of water, advancing by quarters of an inch from one inch to twenty at temperatures varying from 50° F. to 1,000 F.

Velocities have been given both at 50° F. and at 62° F., the former being assumed as the mean atmospheric temperature by American fan makers, while with English manufacturers 62° F. is usually taken to represent normal thermometric conditions.

From 300° F. to 500° F. the velocities are given at temperatures advancing by increments of 50° F., as these are the temperatures commonly met with in induced draft practice.

These tables are very approximately correct, and will be found of use in making calculations from the tables of tests to be given later, in which the majority of the values are given in velocity ratios and not in pressures.

It may be added that an allowance has been made in these tables for the reduction in velocity due to the increased density of the air accompanying its mechanical compression.

In order to compute the amount of work done by a centrifugal fan in any particular case, it is necessary to know the volume of the air delivered by it per unit of time, and the pressure difference per unit of area, at the fan's inlet and outlet respectively, or, as the latter is usually expressed, the water gauge set up.

It is usual in this country to express the volume discharged in cubic feet per minute and, as stated above, the pressure difference in inches of water. If the effective area of flow be known, the number of cubic feet delivered per minute will be the product of the former in square feet, and the velocity of the air in feet per minute.

For measuring the work done by a fan, four methods will be referred to: (1) that of chemical analysis for the volume in cubic feet per minute; (2) the use of the anemometer; (3) the use of the manometer, or water gauge for finding the pressure in inches of water; and (4) of the "Pitot" tube for ascertaining the velocity in feet per minute.

*Chemical Analysis.*—This method has been successfully employed in the case of centrifugal pumps, and consists in adding to the liquid or gas on its way into the pump or fan some suitable chemical at a known rate, and by analysis of the liquid or gas discharged, ascertaining the percentage of the added chemical present, and thus deducing the total volume dealt with.

This method is quite frequently employed in testing fans that have been installed in connection with boilers for the purposes of induced draft. Referring to the matter but briefly, the method employed is to make a careful analysis of a sample of the flue gases taken near the fan inlet. The percentages of carbonic acid and of carbonic oxide present (if any of the latter) can by a

simple analytic process be easily ascertained, and thence the ratio of carbon burnt to the total quantity of gas handled by the fan.

If the net weight of coal burnt in the furnaces in a given time be accurately measured, it would appear that an analysis of the coal used makes the number of cubic feet of gases handled per minute by the fan a matter for simple calculation. A good deal of circumspection, however, should be exercised both in the making of such tests and in deciding the amount of reliance to be placed upon them when made.

The number of observations to be made leaves room for the sum of possible small errors to become a serious consideration, and the difficulty of obtaining a representative sample of the flue gases is by no means negligible.

As the specific gravity of carbonic acid gas is considerably greater than that of any other of the constituent flue gases, it may be reasonably assumed that where the flues are of any considerable length larger percentages of carbonic acid gas would be found at the lower parts of the flues, and at the outer radii of flue bends.

This the writer has found to be the case, and at a certain large power station has been informed by the engineer in charge that a sample of gases can be taken at a particular section of the flue to contain any required percentage of carbonic acid gas from 6 to 16 per cent.

However, with judgment, care, and practical experience in the carrying out of such tests, fairly accurate results may be obtained.

*The Anemometer.*—An instrument very largely used for the measurement of the rate of flow of air is the anemometer, and where the velocity is low and the flow uniform this is perhaps the best instrument that can be used for the purpose.

But for testing centrifugal fans, the velocity of the current of air discharged from which is extremely irregular, the anemometer should be used with caution.

The instrument is usually calibrated by rotating it at the end of a radius bar through still air at a uniform speed. There seems to be no doubt, however, but that the anemometer when so tested carries round with it on its circular path a certain amount of air, instead of allowing all the air it meets to pass through it.

The Prussian Mining Commission, whose work has become classical, tested in 1884 a number of anemometers by driving air through them from a gas holder, the volume of air passed being thus capable of very accurate measurement.

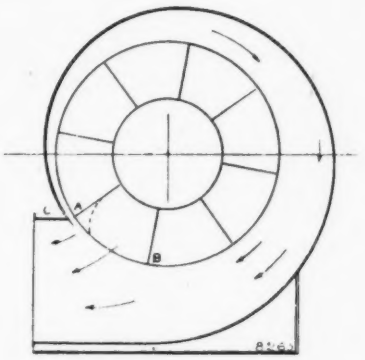



FIG. 2.

When thus tested it was found that the anemometers exaggerated the actual velocity of the air by an amount varying from 7 to 13 per cent.

This error, however, would be greatly exceeded were the anemometer placed in the line of discharge from a centrifugal fan, the velocity of flow from which is very far from being uniform.

Referring to Fig. 2, it will be seen that when the lip of a blade *A* is just opposite the throat of the fan at *C*, air is being discharged through the whole of the peripheral space between the blade *A* and the following blade *B*. As the blade *B*, however, is approaching in turn the throat *C* of the fan the area available for discharge between these two blades is being gradually contracted until the blade *B* is opposite the fan throat, when this discharge is entirely cut off.

The pulsations due to this cause in the column of air flowing out of the fan are frequently made evident by the loud organ note produced by many fans when run under certain conditions, the narrow fans used for destructor work often being serious offenders in this respect. It will be evident that the rounding of the throat, or the backward curvature of the blade as shown in the figure, will have the effect of lessening this nuisance.

Even if the pulsations are too slow or too rapid to produce a musical note, there is no reason to suppose that they cease to exist.

In other fans of the "Ser" and "Mortier" type where a large number of blades of small radial depth are employed, the air is picked as the blade is moving at a comparatively high velocity, and a sudden

compression of the air takes place while the latter is passing through the blades. The compression and the subsequent re-expansion also tend to cause pulsations in the air discharged. The effect of this irregularity of flow on the reading of the anemometer can be easily seen by placing the instrument alternately for equal periods of time in a strong current of air and in still air. It will be noticed that the anemometer continues to rotate for a considerable time after being placed in still air, but on being returned into the moving air the vanes quickly pick up the speed of rotation due to the velocity of the air. It is thus obvious that the reading obtained will be much higher than if the anemometer had been placed for half this period of time in the moving air, and the volume of air air discharged will be correspondingly exaggerated.

The writer believes from his own experience under such circumstances, that the anemometer when placed in a strong current of air discharged from a fan, will exaggerate the amount of air discharged by from 20 to 30 per cent.

Another by no means negligible objection to the anemometer as an instrument for every day use is its extreme fragility. Unless the greatest care is used in handling a slight distortion of the vanes, and the consequent inaccuracy in the readings given, will ensue. An anemometer returned through the parcel post after calibration at Kew may still lead the unwary astray.

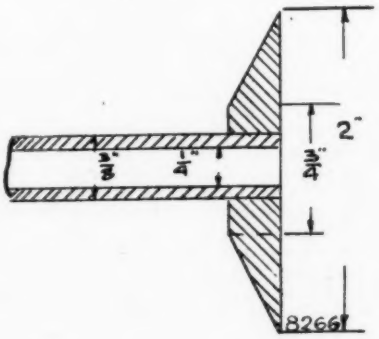
*The Manometer.*—For measuring the pressure set up by a centrifugal fan, a manometer or water gauge is the instrument most generally employed. It consists essentially of a piece of glass tubing bent to the form of a U, the top of one leg of which is generally open to the atmosphere, the top of the other leg being connected by an india-rubber tube or other means to the enclosed space, the pressure in which it is desired to record.

Provided that the enclosed air is at rest, its pressure in inches of water can be accurately read by observing the difference in level of the surfaces of the two columns of water in the gauge, but if the tip of the tube leading to the water-gauge is placed in a strong current of air, the water-gauge reading obtained may be extremely unreliable unless proper precautions are observed. When used for measuring the pressure in a duct through which a current of air is flowing the tip must be placed exactly at right angles to the direction of flow, otherwise the height recorded in the gauge will be increased or decreased according as the tip is facing towards or away from the direction from which the current is flowing.

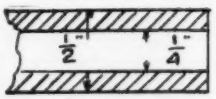
Even when the tip is fixed exactly at right angles to the current, the inductive action of the air flowing over the end of the tip tends to diminish the pressure recorded, and with some forms of tip the error introduced by this inductive or asperating action of the air current is considerable. Messrs. Heenan and Gilbert, in a paper read before the Institution of Civil Engineers, gave some very valuable information with regard to tests which they had been conducting with side tips. The method adopted for carrying out the tests with these tips was briefly as follows:—

The tip to be tested was screwed into a horizontal pipe about 9 ft. long, and this in turn was fixed to a hollow vertical spindle from which, by means of a stuffing box, a connection was taken to an ordinary water gauge.

The vertical spindle was rotated at a known speed, thus driving the tip through a circular path at a uniform speed. If there were no




4·9 to 6·8




42 to 51.

42 to 49.

FIG. 3.—ADDITIONAL GAUGE READING PER CENT., DUE TO INDUCTION.

inductive action due to the air flowing over the face of the tip, the reading on the water gauge would be that due to the vacuum set up in the horizontal revolving pipe by the centrifugal force acting on the air within it, and it is evident, as previously shown, that if $P_1 - P_2$ be the difference between the pressure at the centre of the vertical spindle and that at the tip, that is to

$$\frac{P_1 - P_2}{D} = \frac{v^2}{2g},$$

say, the reading in the water gauge will be due to the pressure that would be required to give an air velocity equivalent to that at which the tip is being driven.

In these experiments, however, it was found that in addition to the vacuum just mentioned, an additional negative reading was given, amounting with one form of tip to 51 per cent. of the reading due to the centrifugal force.

In Fig. 3 are given three of the forms of side tips tested along with the additional gauge readings per cent. due to induction.

The form of side tip marked (1) in Fig. 3 was recommended to the authors of the paper by Prof. Unwin, and it was thought possible that with this form of tip the inductive action of the air was entirely neutralised, and that the small additional gauge reading shown was due to a certain amount of the external air being carried round with the tip; but this is very doubtful. In any case it is evident that in measuring, by means of a manometer, the vacuum set up by a centrifugal fan, the work done may be greatly exaggerated unless a suitable tip is used.

*(To be continued.)*

# A Large Coal Tip at Port Talbot.

THE coal hoist and tip illustrated on the next page is one of the largest and most powerful appliances of the kind in Great Britain, and was constructed at the new dock of the Port Talbot Railway and Docks company for the rapid coaling of the largest steamers entering the Bristol Channel. The jetty upon which it stands and the approach viaduct are built in concrete-steel ("Hennebique" system) and constitute the first application of the material to the purpose in question.

The framework of the coal tip is a steel tower 70 ft. high, measuring 40 ft. by 28 ft. in plan, the hoist proper having the total lift of 55 ft. above quay level and 35 ft. above the gantry. It is capable of raising loaded railway trucks up to the gross weight of 30 tons at the rate of 120 ft. per min. and of lowering empties at the rate of 180 ft. per min.

The bedplace of the tip is built up of massive box girders and the main tower together with its projecting wing and buttress is constructed of ordinary rolled steel sections. The weight of the hoisting cradle in which coal trucks are raised to the required height is counterbalanced in part by weights suspended from wire ropes working in grooves formed in the uprights at the landward side of the tower, a sufficient proportion of the weight being left unbalanced to provide for the descent of empty trucks by gravity. The tipping table, 24 ft. long, is pivotted so that it can be set to any required angle, and the tower is provided with a 4-ton "anti-breaking" crane for lowering coal in skips, this crane having the total lift of 65 ft., the maximum radius of 30 ft. and the minimum radius of 12 ft.

Power for working the hoist, the tipping table, and the "anti-breakage" crane, is furnished from hydraulic rams supplied with water under the pressure

COAL TIP AT PORT TALBOT.

of 750 lb. per sq. in. from the hydraulic mains of the company. For operating the cradle of the hoist two pairs of direct-acting hydraulic rams are fixed between the main centre girders of the tower, the head of each ram being attached to the cross beam at the top of the cradle. One pair of rams, with the diameter of 10½ in., is used for hoisting trucks up to 12 tons gross weight, and the other pairs of rams with the diameter of 6 in. is brought into use when the maximum load has to be raised.

Power for operation of the tipping table and the auxiliary crane is furnished by other hydraulic rams fixed at the sides of the tower.

All the rams are controlled from a valve house built on the upper platform of the tower.

The general arrangement of the hoist is similar to that of kindred appliances previously installed at Port Talbot, but this example is of far more powerful and of proportionately massive construction, its total weight being nearly 200 tons.

It may be of interest to state that the railway approach lines, or "load roads," to the new coal tip provide storage accommodation for fully 3,500 tons of coal distributed over five sidings in such a way as to facilitate the ready marshalling of trucks, and the blending of coals. Other railway lines, known as "light roads," are used for empty trucks returning from the tip and are capable of accommodating about 120 trucks. The gradients of the load and light lines are arranged so that loaded trucks gravitate to the tip, and empty trucks from it, thus rendering unnecessary the employment of locomotives except for bringing coal to the siding and for the removal of empties.

In order to provide for this economical method of working it was necessary to build embankments with the total length of 1,500 ft., the level of the load line for five trucks abreast being some 20 ft.

COAL TIP AT PORT TALBOT.

higher than that of the light line. Weighbridges, a hydraulic turntable, and two hydraulic capstans have been installed in suitable positions for weighing full and empty trucks and for the expeditious handling of traffic.

The whole of the works with the exception of the coal tip were designed by Mr. W. Cleaver, the chief engineer to the Port Talbot Railway and Dock Company. The coal tip was constructed to the designs of Mr. A. H. Hertz, the locomotive superintendent to the company, by Messrs. John Abbott & Co. of Gateshead, the weighbridges were supplied by Messrs. Pooley & Sons, and the turntables by Messrs. W. Richards & Son, of Leicester.

# Some New Uses for Reinforced Concrete.

*By W. NOBLE TWELVETREES, M.I.Mech.E., A.M.I.E.E.*

So many papers have been read of late, discussing the general principles governing the design of reinforced concrete structures and describing works of familiar character in which reinforced concrete has been adopted as the material of construction, that the author thinks it well, on the present occasion, to follow a somewhat less frequented path.

Under the title selected for this paper he considers briefly some types of construction that have not yet been applied in this country, others that have been adopted only quite recently, and others again that are not new in themselves but are suitable for employment in novel directions.

(1.) In the first category may be placed such constructions as railway sleepers, standards for overhead electric cables in power transmission and electricity distribution systems, and poles for telegraph and telephone wires.

Reinforced concrete railway sleepers are to be found on several lines in the United States. Fig. 1 contains details of the "Campbell" sleeper; some 150 of which were laid down on the Elgin, Joliet and Eastern Railway in 1905, and 1,000 on the Chicago, Lake Shore and Eastern Railway during last year. This sleeper is of concrete, reinforced by two old locomotive boiler tubes and a surrounding ring of wire netting. According to the published results of tests, the "Campbell" sleeper is capable of withstanding loads up to 80,000 lbs. applied at the rail seat, before showing signs of failure by crushing, and of supporting transverse loads up to 10,000 lbs. applied at the middle, the rail seats being supported on blocks at the distance of 5 ft. apart. Fig. 2 illustrates the type of sleeper adopted on the Chicago

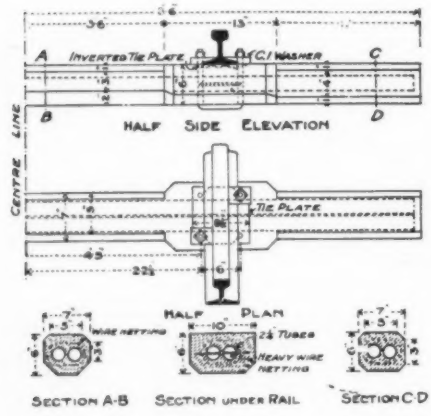



FIG. 1.

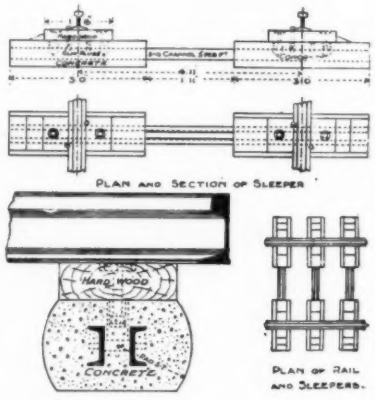



FIG. 2.

and Alton railroad by Mr. G. H. Kimball. Sleepers of this type have been in service on that line since 1901, and have proved capable of withstanding the effects of heavy traffic in a perfectly satisfactory manner.

The sleeper consists of two blocks of concrete, each 3 ft. long, by 7 in. thick, by 9 in. wide, connected by two 3 in. steel channel bars embedded in the concrete blocks. The rails are secured by spikes upon hardwood blocks intended to absorb shocks and distribute pressure. The small drawing at the right-hand bottom corner of Fig. 2 shows three of the sleepers as laid on the permanent way.

Other types of reinforced concrete sleepers are in use on several American railways, and the fact that the employment of the material for the purpose has been taken up seriously in a great timber-growing country should serve as a hint to railway engineers in this country, where the cost of timber tends to increase year by year.

The "Caio" sleeper, adopted experimentally on the Italian railways in the year 1900, has shown satisfactory results and it is stated that the authorities have decided to lay 300,000 sleepers of the same type. As shown in Fig. 3, the sleeper is reinforced in a somewhat complicated manner by longitudinal steel rods interlaced with wire, while vertical rods and netting are placed beneath the chair seats and some netting in the middle portion of the sleeper.

Reinforced concrete poles have been used for some time past for carrying the cables employed in power transmission systems in various continental countries. An improved method of construction has recently been introduced by Messrs. Siegwart, of Lucerne, for the production of hollow poles by means of a special machine, the poles being made to any required length and taper, and the concrete reinforced suitably for the length and the load to be carried.

Reinforced concrete standards for power transmission lines are coming into extensive use in the United States. Fig. 4 contains full details of the standards for a three-phase power transmission line, the standards being 49 ft. $7\frac{1}{2}$ in. high with a minimum clearance of 30 ft., reinforced with twelve $\frac{3}{4}$ in. and $\frac{7}{8}$ in. longitudinal bars and a spiral winding of $\frac{1}{8}$ in. steel wire. Commencing at the top of Fig. 4, and reading from left to right, we have—after the general elevation—a detail of the top pin and socket, a part elevation of one of the lower cable pins and below these two drawings a plan of the pin bracket. The next details to the right illustrate the

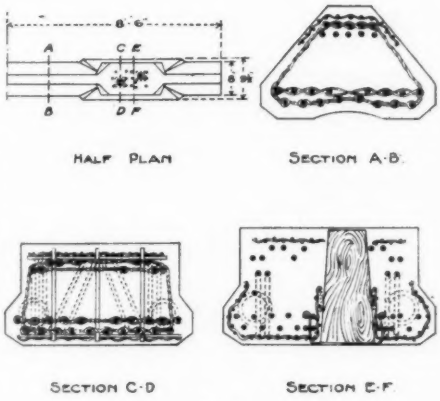



FIG. 3.

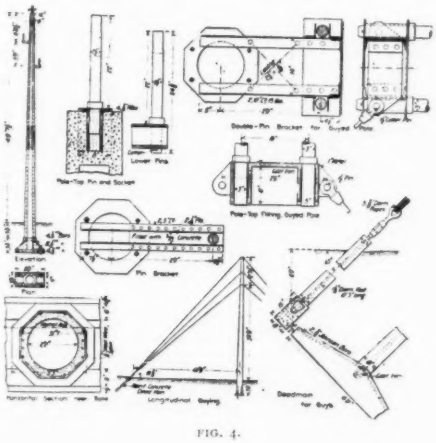


FIG. 4.

double pin bracket employed for standards intended to be guyed, the top fitting for guyed standards being shown below. The system of guying is illustrated in the two drawings at the bottom right-hand corner, the remaining detail being a horizontal section of the standard near the base.

The utility of reinforced concrete for the purposes now under consideration should appeal to the Post office and railway companies, as well as to those concerned in electricity undertakings, since reinforced concrete is an ideal material for the construction of telegraph and telephone poles. An instance of enterprise in this direction has been afforded by the Pennsylvania Railroad, by whom a mile of telegraph poles was erected in the autumn of last year. The poles, from 23 ft. to 34 ft. long, were made of concrete, reinforced with twenty-four $\frac{1}{4}$ in. rods, their transverse dimensions were 8 in. square at the bottom tapering to 6 in. square at the top, the corners being chamfered so as to give an octagonal cross-section above the ground level. The work was hurried so as to have the line ready for inspection at a given date, and in consequence some of the poles were erected within five days after they had been made. Notwithstanding this hasty construction and the severe windstorms of last winter, it is stated that the poles were in almost perfect condition in May this year.

(2.) Foremost among examples in the second category, of new uses for

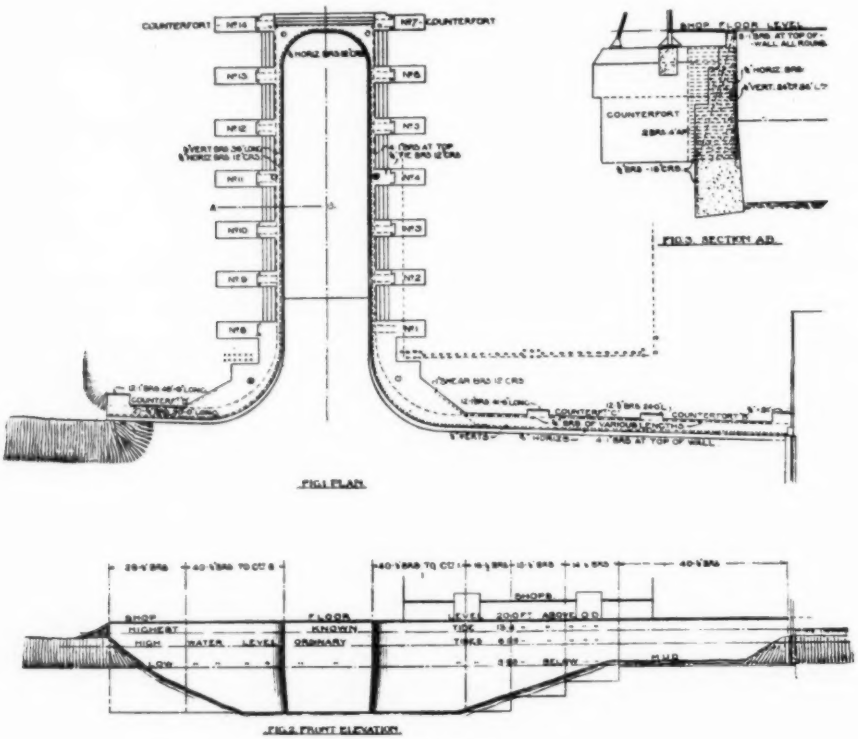



FIG. 5.

reinforced concrete, should be mentioned the Scotstoun dock recently completed on the Clyde for the Coventry Ordnance Company. As an entirely new departure in marine engineering, this work deserves consideration.

This dock (Fig. 5) is small as such works go, having the length of 176 ft., the width of 48 ft. and the depth of 50 ft. from quay level to the bottom. The walls are reinforced by a network of "Indented" patent steel bars and are strengthened by fourteen counterforts which also serve the purpose of supporting the gantry for a heavy travelling crane. The detail at the right-hand top corner is an enlarged section showing the construction more clearly. The dock walls curve outwards at the entrance and merge into quay walls measuring 188 ft. and 47 ft. long on either side, as shown in the plan. The design as a whole represents sound and substantial construction, the concrete being monolithic throughout, and reinforced in such manner as to afford ample resistance to tension and to guard against the development of temperature cracks.

Another novel and useful application of reinforced concrete to marine engineering is to be found in the breakwater built as a protection to the fishing harbour at Passage East in the estuary of the River Suir, near Waterford (See Fig. 6.) This work, built by the Irish Board of Public Works in accordance with the "Hennebique" system, is 120 ft. long by about 20 ft. wide. The foundation consists of a cofferdam made by driving reinforced concrete grooved sheet piles, from 15 ft. to 30 ft. long, according to the depth of the river bed, formed into a water-tight wall by dowels of cement grout filled into the adjacent grooves in the sides of the piles. The cofferdam was filled up with rubble, and from its upper edge was built up a super-structure consisting of reinforced concrete columns, walings, diagonal bracing, longitudinal and transverse deck beams, with lateral curtain walls and a continuous decking. All these portions of the structure are monolithically connected and reinforced by a complete network of steel bars. A breakwater of this kind would manifestly be inadequate for the open sea, but in comparatively sheltered positions, where trouble is caused by waves of moderate size, it is entirely suitable, as demonstrated by the behaviour of the work here illustrated.

Figs. 7 to 9 illustrate the sea-wall and protective slope designed by Mr. Nelson F. Dennis, the borough engineer of West Hartlepool, and built under his direction between that town and Seaton Carew. The total length of the work is about two miles. It commences at Seaton Carew as a retaining wall, the batter of which is gradually increased until the wall merges into the protective slope. The retaining wall, as may be seen by Fig. 7, consists of a foundation slab, counterforts, and a face wall, and the structure is prevented from sliding seawards by timber piles and walings. All parts of the construction are reinforced by expanded metal, so that the quantity of concrete necessary was reduced to an absolute minimum. This will be realised when it is stated that

FIG. 6.

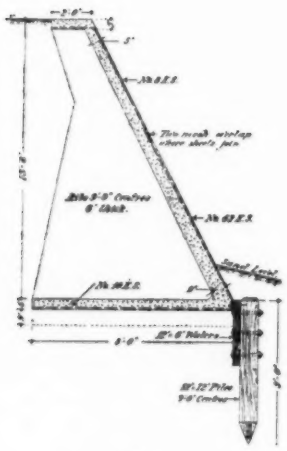


FIG. 7.

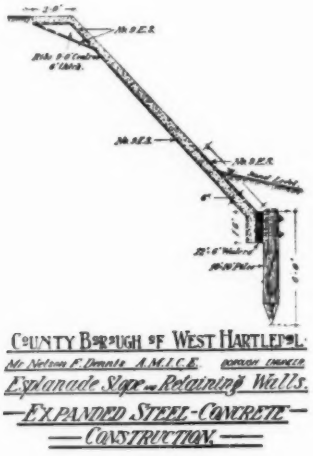

COUNTY BOROUGH OF WEST HARTLEPOOL.
Mr. Nelson F. Dennis A.M.I.C.E. BOROUGH ENGINEER.
Esplanade Slope and Retaining Walls.
EXPANDED STEEL-CONCRETE
CONSTRUCTION.

FIG. 8.

the foundation slab is only 6 in. thick, the counterforts 6 in. thick, and the face wall 9 in. thick at the bottom and 5 in. thick at the top. Although the construction is very light, stability against overturning is assured by the weight of the earth filled in behind the face wall and resting upon the counterforts. Fig. 7 is a section of the construction beyond the border of Seaton Carew. Fig. 8 is a section of the protective slope, whose inclination is further increased near the town of West Hartlepool. As in the case of the retaining wall, the toe of the structure is prevented from sliding downward by being butted against timber piling and waling pieces.

Fig. 9 is a view showing part of the protective slope during the process of concreting.

Another application of reinforced concrete to coast defence works is illustrated by the protective wall and promenade at Hornsea, on the Yorkshire coast, designed by Mr. W. T. Douglas, M.Inst.C.E. Fig. 10 represents the construction of the lower promenade upon the plain concrete sea wall. The promenade is of concrete reinforced with expanded metal, and is stiffened by ribs of the same material at distances of 7 ft. 9 in. apart. On the top of the cliff there is an upper promenade, and as the soil is of extremely friable nature, the surface of the cliff has been protected by a reinforced concrete wall, 9 in. thick at the bottom and 4 in. thick at the

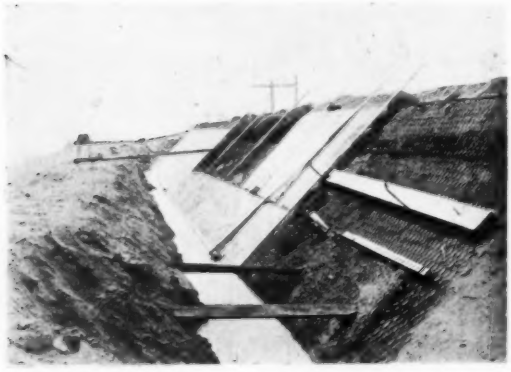


FIG. 9.

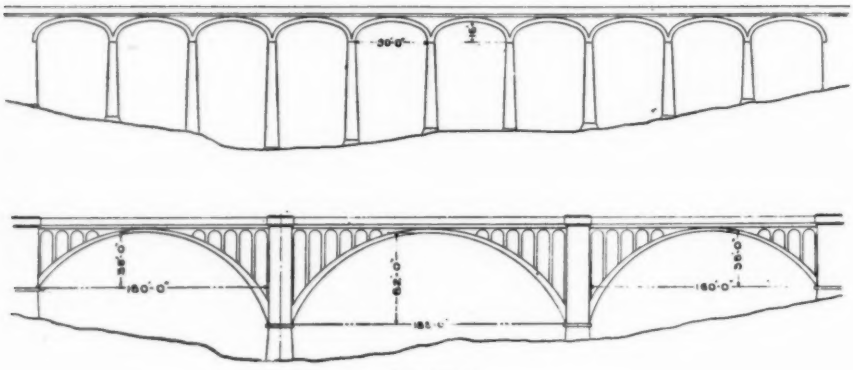
top, with buttresses at intervals of 7 ft. 9 in. apart. Fig. 10 shows the reinforcement in position for the protective wall. In Figs. 11 and 12 we have two views illustrating the application of reinforced concrete to the construction of groynes for foreshore protection at Roedean, near Brighton. These groynes, patented by Dr. J. S. Owens, A.M.Inst.C.E., consist of standards driven as piles, or otherwise secured in the shore at suitable intervals apart. As represented in Fig. 11 they are made with grooved sides, so that reinforced concrete slabs can be slipped in place between them, and fresh slabs be added as those first applied are covered by the accretion of beach material. The standards and slabs are made in accordance with the "Hennebique" system, and in addition to the superior durability of the material as compared with timber, its weight is an important factor, causing the slabs to sink down to any altered contour of the beach in consequence of under-runs. Fig. 12 shows the upper end of a groyne at Roedean; this part of the construction being near the cliff, where a large accumulation of shingle is expected. It also shows the method of strutting high groynes of this type.

FIG. 10.

FIG. 11.

Turning now to a work of a different class, it may be pointed out that several reinforced concrete bridges for railway traffic are already to be found in Great Britain. These may be considered as stepping-stones towards the application of the same material to the building of important railway bridges and viaducts for main-line traffic.

FIG. 12.



FIGS. 13 AND 14.

In addition to its superior durability as compared with that of steel, reinforced concrete permits the realisation of light and graceful designs that are out of the question in brick, stone and plain concrete. This point is illustrated by Figs. 13 and 14, where the upper sketch is the elevation of a plain concrete railway viaduct, built a few years ago in the South of England. The viaduct is 600 ft. long, and includes ten arches of 50 ft. span. Owing to the unstable character of the ground and the weight of the structure, considerable trouble was caused by settlement, and especially by a land-slip near the western abutment and the adjacent pier, the effect of the subsidence being to crack the first arch at the crown.

Fig. 14 shows the viaduct as it might have been built in reinforced concrete without exceeding arch spans already realised in actual practice. In a design of this character, the outward thrust of the arches would naturally oppose any tendency of the embankment to slide downwards, and in unstable ground perfect stability of the foundations could easily be secured by building them upon reinforced concrete piles driven down to a sufficient depth.

An example of far bolder design than that suggested is afforded by the Plougastel bridge (Fig. 15), authorised for construction by the French Government and designed in accordance with the Considère system of hooped concrete. This bridge includes two cantilever and bowstring girder spans of 317 ft. 9 in., two latticed girder spans of 106 ft. 7 in. and one similar span of 52 ft. 6 in., apart from the swing span at the right-hand end, which is to be built in steel. The bridge will carry road traffic and an electric tramway.

Another striking example of reinforced concrete railway viaduct construction is to be found in the extension of the Florida East Coast Railway from the mainland to the island of Key West. The new line is being carried across the series of islands known as the Florida Keys, and for some seventy-five miles of its length will cross the sea on

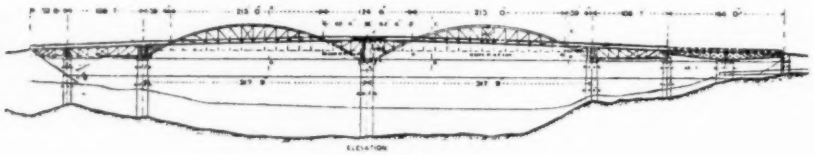


FIG. 15.

embankments and viaducts. In places where the depth is considerable and the channels are exposed to storms, reinforced concrete viaducts will be built, ranging in length from nearly a mile to more than two miles each.

Fig. 16 is part of the longest viaduct now in course of completion. The structure comprises 217 arches of 50 ft. span, supported on piers rising from the sea bed 10 ft. to 30 ft. below the surface, and carrying the railway at a height of 31 ft. above water level. It will probably be conceded that the construction of these viaducts shows that American railway engineers are quite prepared to accept reinforced concrete as a trustworthy and durable material for use under exceptionally trying conditions.

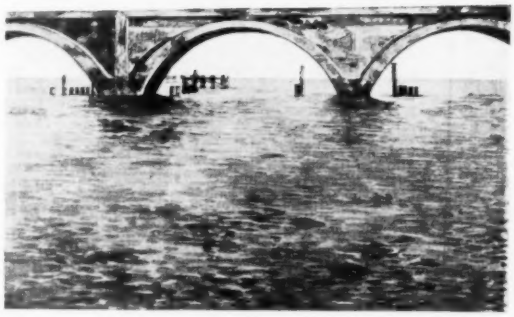


FIG. 16.

As final illustrations of reinforced concrete railway bridges and viaducts, two views are given of other typical structures in the United States.

Fig. 17 is a photograph of the Danville double-track bridge, with two spans of 80 ft. and one span of 100 ft., on the Cleveland, Cincinnati, Chicago and St. Louis Railroad, this work having been designed on the "Indented Bar" system.

Fig. 18 is a view during construction of the double-track railway viaduct, designed on the "Kahn" system of trussed concrete, for the Richmond and Chesapeake Bay Railroad across the city of Richmond. This viaduct is about $\frac{3}{4}$ mile long, in some places it is 80 ft. high, and it is said to be the longest reinforced concrete construction hitherto completed.

Several graceful highway bridges of moderate span have been erected in Great Britain on the "Hennebique" and other systems, but the claims of reinforced concrete as a material for spanning important rivers still remains to be recognised in a practical manner. In France we have the Decize bridge on the Loire with two arches of nearly 184 ft. span; in Belgium the

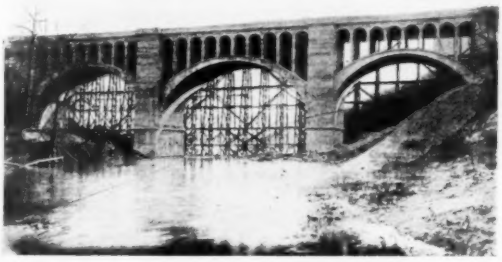


FIG. 17.

FIG. 18.

River Our, the bridge at Liége with a central cantilever span of 180 ft.; in Bavaria, the Isar river bridge at Grünwald with two arches of 230 ft. span, and girder approaches bringing the total length up to 700 ft.; in Spain, the Bormida bridge with an arch span of 167 ft.; in Portugal, the Pena river bridge with five arches of about 115 ft. span; and in the United States the National Memorial bridge across the Potomac, having the total length of 3,400 ft., and including six reinforced concrete arches of 192 ft. span.

All the foregoing are fine bridges and some of them are truly monumental. There is nothing approaching them, so far as concerns reinforced concrete, in our own country. Steel girders or arches are usually employed for long span bridges.

Fig. 19 serves to suggest that the necessity for this practice no longer exists. The first drawing represents a steel girder bridge of familiar type, with two spans of 248 ft. and two of 168 ft., carrying a roadway at the height of nearly 90 ft. above a river.

The second drawing gives an idea of what could have been done on the same site in reinforced concrete without involving greater expenditure, embodying a far more graceful type of design, and obviating the necessity for painting and maintenance charges.

In London, when old Vauxhall Bridge was found to be unsafe, the decision was made to replace it by a plain concrete structure. Unfortunately, this involved comparatively short spans and so much weight that it was found necessary in the end to build the arches of steel in order to reduce the load upon the foundations. If reinforced instead of plain concrete had been decided upon at the outset, all essential conditions could have been satisfactorily met, and the bridge might have been made a really fine example of progress in constructive work as well as an ornament to the metropolis.

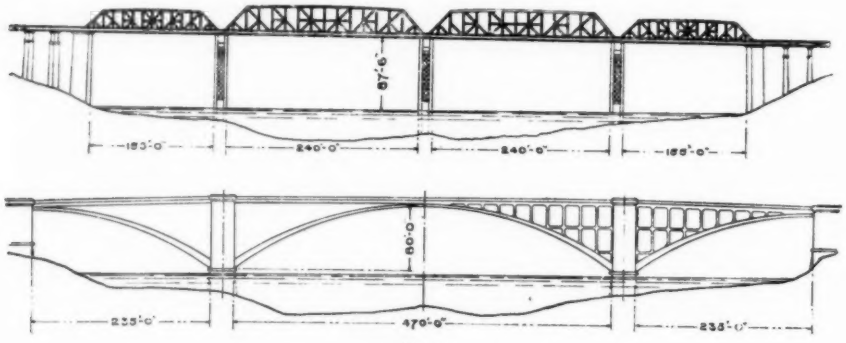



FIG. 19.

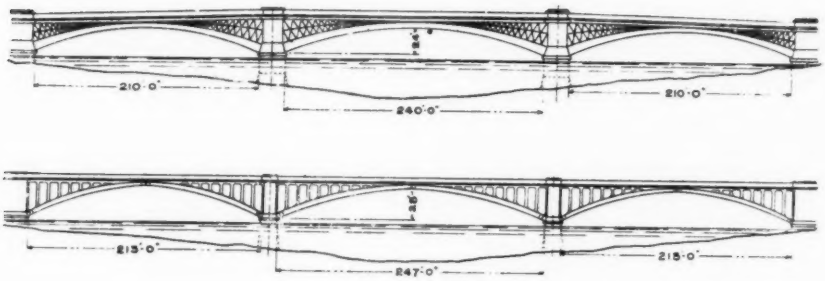



FIG. 20.

As Southwark Bridge will be rebuilt at no distant date, the opportunity offers for the erection of a structure worthy of being ranked with the great reinforced concrete bridges of the world. There would be no difficulty in spanning the river by three arches of approximately the same length as those in the existing bridge.

Fig. 20 contains outline elevations of the existing bridge and the general character of the design suggested by the author.

The three spans would be much lighter than either the present cast-iron arches or solid masonry. Consequently the risk of any trouble such as that experienced in connection with the rebuilding of Vauxhall Bridge would be avoided.

The aesthetic treatment of a bridge such as this is a matter scarcely coming within the scope of the present paper, and the author contents himself with an expression of the opinion that with architectural co-operation engineers should have no difficulty in dealing with reinforced concrete so as to make any structure of the kind pleasing to the eye as well as appropriately expressive of the constructive design and of the material employed. Unfortunately there is a tendency amongst engineers to hide the true features of reinforced concrete construction by attempting to reproduce mere imitations of masonry structures, instead of developing the exterior in harmony with the mechanical principles actually involved.

Passing on to the third category, attention will now be drawn to structures illustrating the suitability of reinforced concrete as a material for the construction of railway station roofs, locomotive depôts, and bridges over railways, wherein steel work is particularly liable to corrosion by reason of its exposure to steam and destructive gases from locomotive engines and boilers.

Fig. 21 is a part elevation of the principal façade of the Renommée Hall, at Liége, a building constructed entirely in reinforced concrete and suggesting the adaptability of that material for the design of rust-proof and fire-proof railway stations. In this particular structure the roof comprises a terrace and three domes, each 55 ft. diameter, but it is quite clear that a series of arched roofed spans could very easily be designed on the lines indicated by the drawing.

The fashion for gigantic roof spans, such as those of St. Pancras and Cannon Street, is now on the wane, and the type of construction favoured in the present day is well illustrated by the new roof of Charing Cross station, where latticed girders extend from side to side of the station, with two lines of intermediate supports, and carry several small roof spans arranged on the ridge and furrow system. A similar method of construction would be quite feasible in reinforced concrete by building a series of small roof spans upon transverse girders or upon arched supports of the graceful type suggested by the

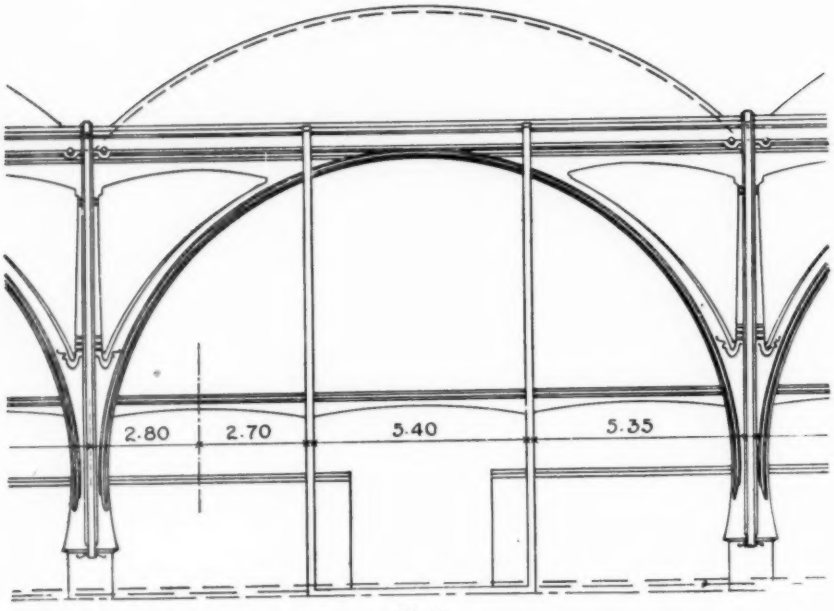



FIG. 21.

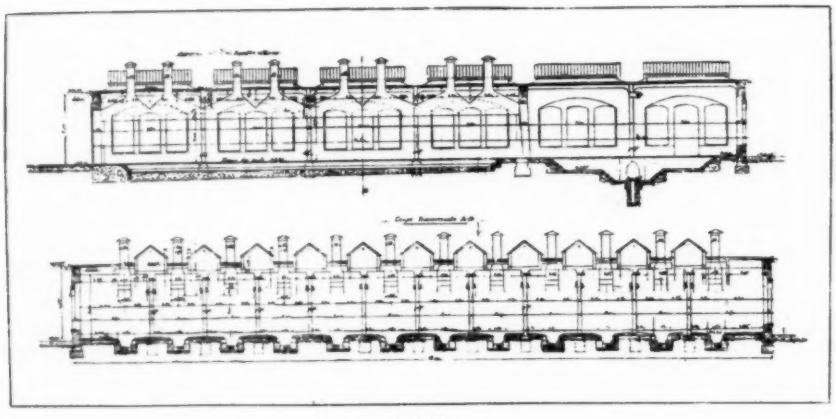


FIG 22.

elevation of the Renommée Hall, Liége.

Another direction in which the use of reinforced concrete should be specially valuable to railway engineers is in the construction of locomotive depôts. The life of steel-work in such buildings cannot be put at more than about fifteen years, and although timber is more durable, the risk of fire is inseparable from its use. Fig. 22 contains part longitudinal and transverse sections of the locomotive depôt built from the designs of Professor Bosset on the Jura-Simplon Railway, near Lausanne, the building being about 165 ft long by 215 ft. wide.

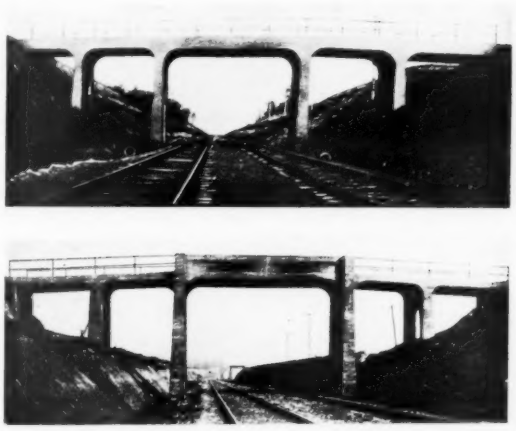


FIG. 23.

It is difficult to understand why reinforced concrete has not yet been applied in this country to the construction of road and other bridges over railways, where the injury caused to steel-work is very serious. The importance of the problem has been fully recognised in the United States, where reinforced concrete bridges are rapidly taking the place of steel structures in country districts as well as in large cities. Fig. 23 contains views of two overhead crossings on the Cleveland, Cincinnati, Chicago and St. Louis Railroad, these bridges being entirely of concrete reinforced on the indented bar system.

In a recent paper by Mr. George S. Webster, chief engineer of surveys of Philadelphia, it is stated that the almost total destruction of several iron highway bridges over steam railways, at places where reinforced concrete arches could not be built owing to lack of headroom, has resulted in the design of steel bridges, all the members of which are encased in concrete, and which have concrete jack arches instead of the usual steel trough flooring. Mr. Webster believes that this composite type of structure will be much more permanent and at the same time more economical than steel construction.

Concrete can also be usefully employed for encasing steel bridges with the object of protecting them against corrosion and of hiding the unsightly appearance of the usual girder construction.

FIG. 24.

Fig. 24 is a view of the Wabash Railroad bridge in Forest Park, St. Louis. This is a plate girder bridge with concrete floor, hollow abutments and ornamental balustrade, reinforced on the indented bar system. As all the steel is protected from corrosion, the cost of maintenance is avoided, and, as may be judged by the illustration, the structure cannot be regarded as an eyesore to those making use of the park in which it is situated.

In conclusion, it may be added that reinforced concrete has been largely applied on the Continent and in America to the construction of foot bridges in railway stations, but British railway engineers continue to use steel for the same purpose. If all bridges of the kind now in existence were cased in concrete they would be rendered proof against destructive influences, and the saving in maintenance charges would soon repay the capital expenditure necessary.

[Revised and extended from a paper read before the British Association.]

# Double-Deck Bridge over the River Wear: North-Eastern Railway.

An interesting bridge of the double-deck type involving some novel methods of construction is now in course of construction at Sunderland over the River Wear, for the accommodation of the North-Eastern Railway and for tramway, vehicular, and pedestrian traffic.

The contract comprises the main bridge over the river and nine others on the approach lines, covering altogether a distance of about $1\frac{3}{4}$ miles.

All the bridges are for a double line of railway, and the double-decked main bridge carries a roadway and two footpaths, the latter outside the main girders on a platform beneath the railway. In the centre of the roadway is a single track of tramway lines, and the Sunderland gas and water main are carried across on the ends of the cross girders.

The bridge over the river consists of three land spans 200 ft. clear, one river span 330 ft. clear, and north and south approaches.

The approaches are composed of masonry arches, on which is superimposed the steelwork which carries the railway. About 60,000 tons of freestone and a third of a million bricks were used in building these approaches. All the face-work is of red sandstone from Locharbriggs Quarry, Dumfries. The steelwork on the south approach is now about half finished. The material is raised into position by a crane travelling along the finished portion at the railroad level.

The abutments and piers of the bridge are built of Norwegian granite, about 40,000 tons being used. The main pier on the south side was founded by means of a cofferdam, and on the north side a large steel caisson, 63 ft. long, 35 ft. wide, and 41 ft. deep was sunk 78 ft. below high water level by means of compressed air. The caisson, which weighed about 270 tons when lowered from the staging, is founded on red sandstone, and was lowered to the river by means of hydraulic jacks, the sinking being carried on by a load applied in the customary manner. With the exception of the working chamber and shaft through which

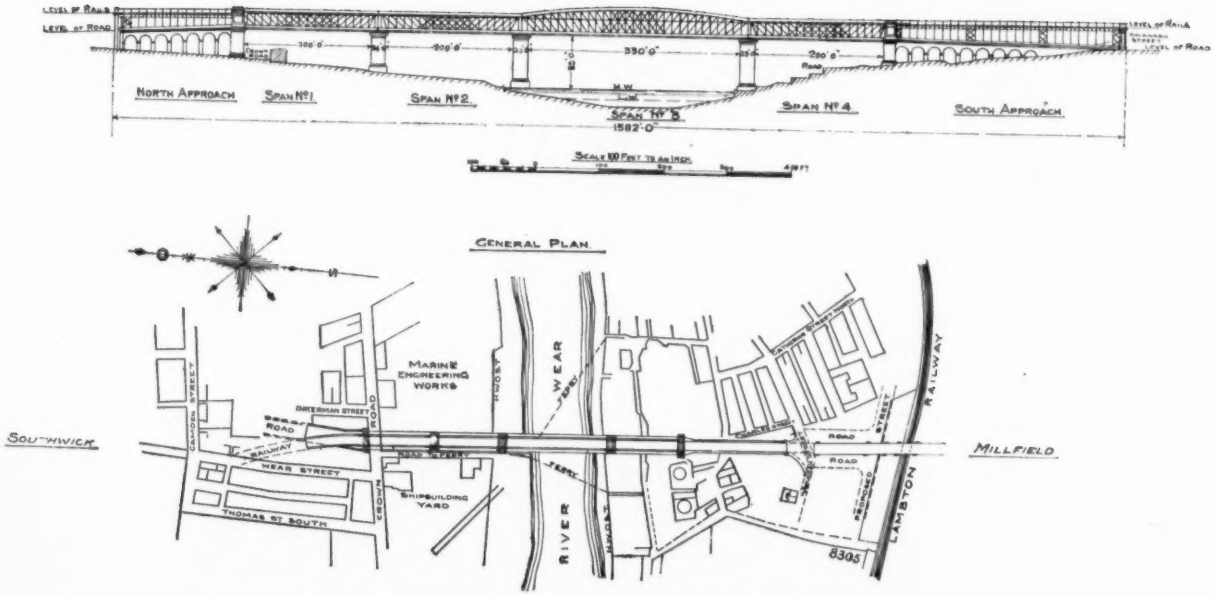



FIG. 1.—GENERAL ELEVATION AND PLAN OF RAILWAY AND ROAD BRIDGE, SUNDERLAND.

material was removed, the whole of the interior of the caisson was filled with concrete. The usual practice of building the masonry pier inside a temporary cofferdam after the caisson had been sunk was, however, at the suggestion of the contractors, departed from. Instead, the masonry was built upon the top of the caisson, airlocks being carried above, so that the work on the pier was always above high-water level. The total height of the pier is 170 ft., of which 44 ft. is comprised by the caisson and the remainder by the granite pier proper. With the superincumbent mass of masonry to above high water level the caisson weighs 8,500 tons.

The 200 ft. span on the south side is now almost completed, and the erection staging will be transferred to the landward of the two 200 ft. spans on the north side.

The main span is to be erected on the well-known "overhang" principle, first brought into prominence on the Forth Bridge. Temporary towers will be erected on the

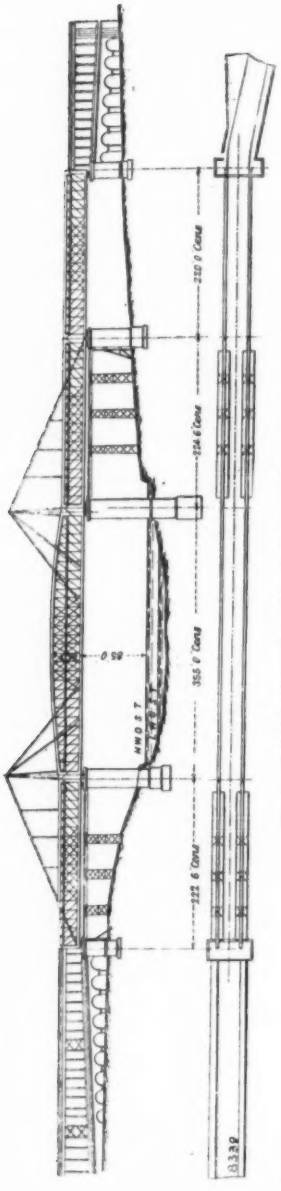



FIG. 2.—GENERAL DRAWING OF BRIDGE SHOWING ERECTION STAGING.

piers, and by means of temporary ties the parts erected will be held up until a junction between the two protruding ends is effected. Each part will be raised into position by means of travelling cranes which will run at the rail level. The towers will be held back by temporary ties attached to the side spans which will thus act as counterweights.

The maximum load to which any set of supporting ties attached to one girder will be subjected is 710 tons.

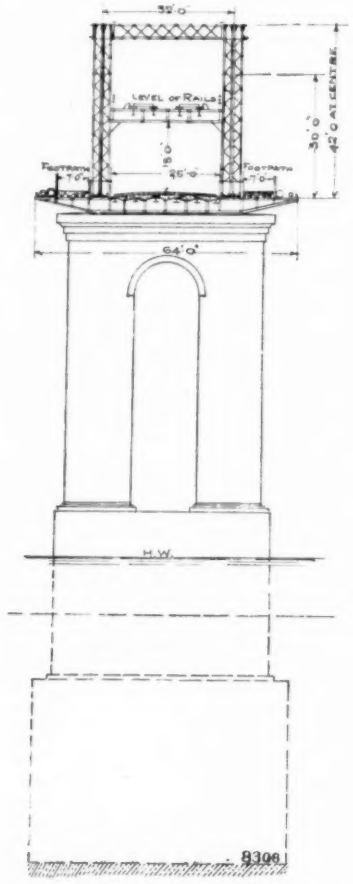



FIG. 3.—CROSS SECTION AT CENTRE OF BRIDGE.

SIDE ELEVATION SHOWING CONNECTION OF C. I DOWNCOMERS TO V POSTS OF MAIN GIRDERS.

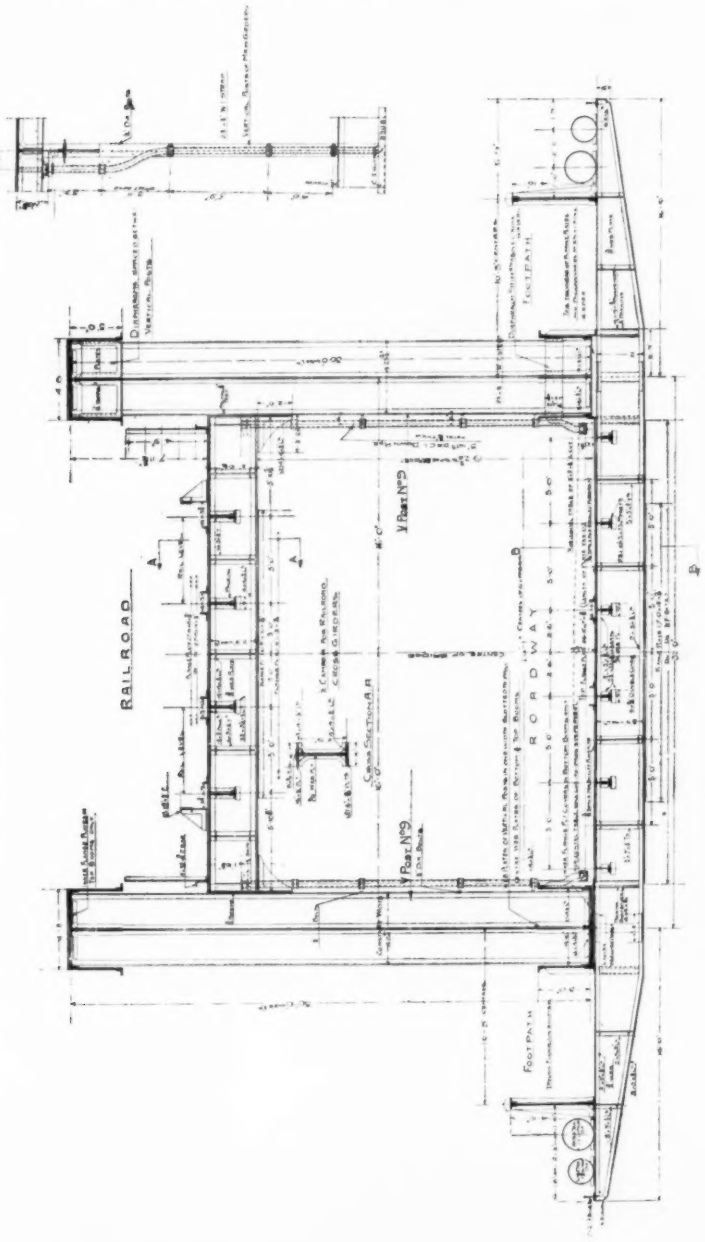



FIG. 4.—CROSS SECTION, 200 FT. SPANS.

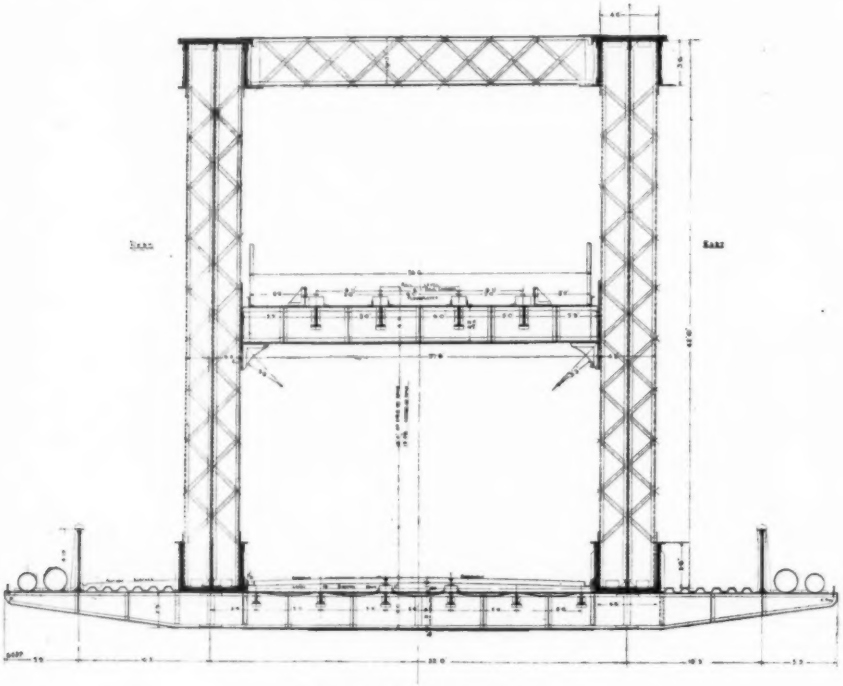


FIG. 5.—CROSS SECTION, 330 FT. SPAN.

The maximum load on each tower will be 760 tons.

The weight of each main girder on the 200 ft. spans is 280 tons, and on the 300 ft. spans 870 tons. The total weights are about 1,400 tons and 2,400 tons respectively. The weight of the steelwork comprised in the whole contract is about 9,000 tons. The main girders vary from 30 ft. in the side spans to 40 ft. in depth in the middle one. The bearing pressure due to each 200 ft. span girder is 350 tons.

The railway approaches the bridge on raised banking, containing about 300,000 cubic yds. of material, and comes on to the first span from a curve of 19½ chains radius and is straight over the remainder of the bridge. The railway level rises from the north to the south, the gradient on the north approach being 1 in 117, and on spans 1 and 2, 1 in 118·16. Spans 3 and 4 are level, while on the south approach the rise is 1 in 200.

The roadway on the bridge consists of ⅜ in. thick inverted buckled plates, covered with concrete with wooden setts on the top. The width between the centres of girders is 32 ft., and on the approaches is 27 ft. 9 in. between centres of columns.

The footpaths are outside the main girders and have a parapet 4 ft. 10. in. high on the outside. They are 7 ft. 6 in. wide, and have trough flooring covered with concrete.

On the ends of the roadway cross girders, which project 5 ft. 9 in. beyond the footpath on each side, are carried the Sunderland gas and water mains. These mains, which are respectively 17 in. and 21 in. internal diameter,

rest on oak blocks shaped to fit the pipes.

Any further description is perhaps best got from the accompanying drawings. Fig. 1 shows a general view of the whole length of the bridge and a key plan to the approaches. Fig. 2 is also a general drawing, but shows the erection staging in position beneath spans 2 and 4, and also outlines the "overhang" erection arrangement for the main span. Figs. 4 and 5 are cross sections on the 200 and the 330 ft. spans respectively.

The entire work was designed by the engineer to the North-Eastern Railway Company, Charles A. Harrison, Esq., LL.D., and the contractors are Sir William Arrol & Co., Ltd., Glasgow, whose Managing Director, Andrew S. Biggart, Esq., has superintended the progress of all the works. The subcontractors for the masonry work are Messrs. Mitchell Brothers, Glasgow.

# RAILWAY ENGINEERING NOTES.

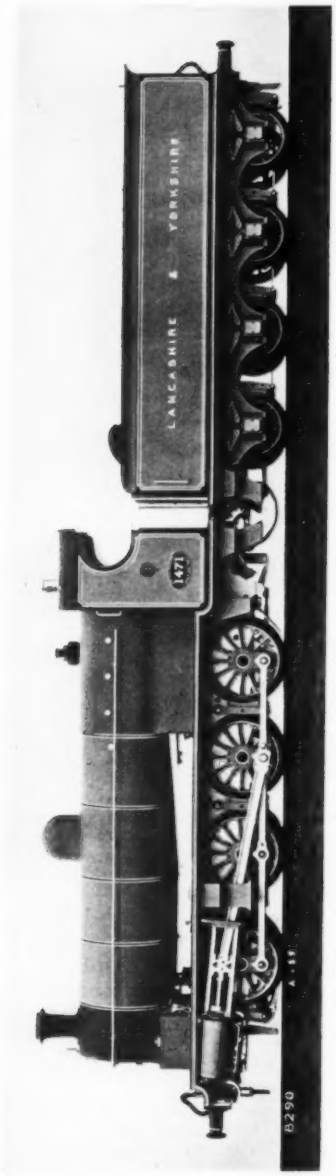
## Compound Goods Locomotive, Lancashire and Yorkshire Railway.

The Lancashire and Yorkshire Railway Locomotive Works, the building of which was commenced in 1886, have just turned out the thousandth engine built there.

The works were erected for the purpose of repairing and renewing the locomotive stock, and of carrying out the mechanical, electrical, and hydraulic engineering work of the railway. The land enclosed for the works comprises 116 acres, of which 22 acres are covered by workshops, comprising offices, stores, boiler shop, smithies, steel, iron, and brass foundries, forge, fitting and machine shops, signal, and points and crossing shops, tin and copper shops, motor and telegraph shops, millwrights, joiners, and pattern shops, erecting and repairing shops, paint shop, chemical laboratory, physical testing room, and gas works. For the carriage of material from the stores and of work to and from the several shops, 7½ miles of tramway lines are laid throughout the works, haulage being performed by a number of small locomotives, the weight of which in working order is 3½ tons.

Mr. Aspinall, the present general manager of the Lancashire and Yorkshire Co., was in at the very inception of the works, and under his direction they were erected, equipped, and organised. The first repaired engine was turned out in December, 1886, and the first new engine, designed by Mr. Aspinall, was built in February, 1889. This was an 8-wheeled radial tank engine (No. 1008). During Mr. Aspinall's period of superintendence as chief mechanical engineer, 667 engines were built, comprising the 8-wheeled radial tank engines previously referred to, 6-wheeled tender goods, 8-wheeled bogie passenger tender engines, and 10-wheeled bogie "Atlantic" type passenger engines. The last named, at the time they were built, were the largest inside cylinder engines in the United Kingdom. A number of small 4-wheeled outside cylinder shunting tank engines were also built for dock work, as well as twenty 6-wheeled outside cylinder shunting tanks.

When Mr. Aspinall took up the duties of general manager for the company, in July, 1899, Mr. Hoy was appointed chief mechanical engineer, and the classes of engines built during the time he held this position included the powerful 8-wheeled coupled coal engines, with "Belpaire" fireboxes, and also twenty of these engines with corrugated flue boilers, very few of which are running on other railways in this country. Mr. Hoy also designed the 10-wheeled radial tank engines, and in all 220 engines were built during his period of office, which terminated in March, 1904, when he received




COMPOUND GOODS ENGINE. L. AND Y. RAILWAY.

an appointment as general manager for Messrs. Beyer, Peacock & Co., the locomotive engineers, of Manchester.

He was succeeded at Horwich by Mr. Geo. Hughes, the present chief mechanical engineer, under whose supervision 113 new engines have, up to the present, been built. He designed the 8-wheeled radial tank engines with "Belpaire" fireboxes and enlarged smokeboxes, and the very powerful 8-wheeled coupled compound coal engines, eleven of which are now running, and the last of which is the thousandth new engine built at these works, as previously referred to, a photograph of which is here given.

The introduction of these compounds may be considered a bold step to take. After very exhaustive trials with one engine, which he had converted from a simple to a compound, Mr. Hughes had evidence that his system of compounding was a good investment, and consequently he decided to build ten more. These ten new engines are slightly modified from the original design, which had all the cylinders driving on to one axle, but in the ten afterwards built the high-pressure cylinders were coupled to the third axle, whilst the low-pressure drove the second axle.

These compounds have four cylinders, namely, two high-pressure 15½ in. diameter, and two low-pressure 22 in. diameter, all of which have a stroke of 26 in. These four cylinders actuate separate cranks, and the engine is termed a balanced compound, as there is always one piston working in exactly the opposite phase to another, so that balanced counter weights in the driving wheels are largely reduced. The high-pressure cylinders are placed outside the frames, and the low-pressure inside. The valves, which are of the piston type for the high-pressure, and Richardson's balanced slide for the low, are so constructed that steam from the boiler is admitted to the high-pressure cylinders through the central part of the high-pressure valves, and after doing duty in these cylinders, exhausts past the ends of the valves through a tubular receiver into the low-pressure steam chest from the ends of the valves, and finally exhausts through the central part into the atmosphere.

The valve motion is the "Joy" pattern, which is the standard used by this company. One motion drives two valves, namely one high and one low-pressure, through the medium of a two-armed rocking shaft. These valves travel together in the same direction, while the pistons move opposite.

FIG. 3.

FIG. 1.

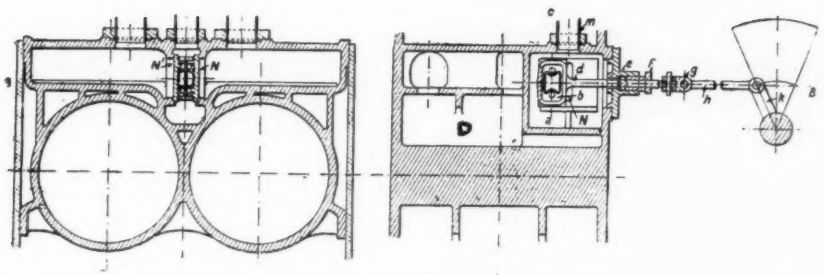
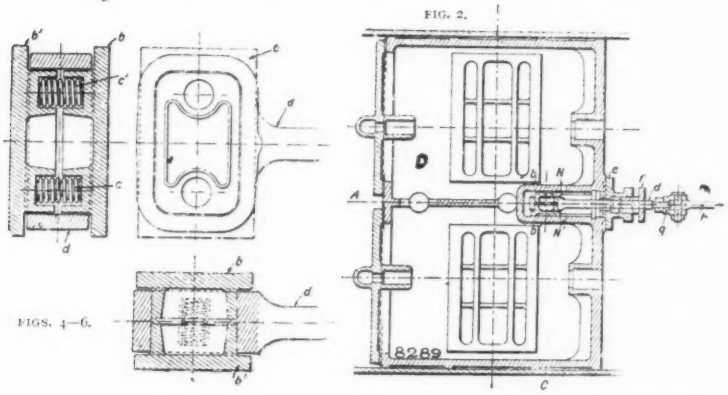


FIG. 2.




FIGS. 4—6.



STARTING AND EMERGENCY VALVE FOR COMPOUND ENGINE. L. AND Y. RAILWAY.

For efficiently starting the engine, or in case of emergency should the engine stall on a bank, Mr. Hughes has patented an arrangement whereby steam direct from the boiler is admitted automatically to the low-pressure steam chest through a starting valve, the details of which are given in the accompanying drawing. When the driver, as is the usual custom, places the reversing lever into either full forward or full backward gear, this operation allows boiler steam to pass into the low-pressure steam chest, and places the high-pressure pistons in equilibrium. No power at this time is given out by the high-pressure pistons—they simply float in boiler steam—but the low-pressure, being of large diameter, namely, 22 in., ample power under these conditions is always available for starting or negotiating loads on banks. This arrangement is extremely simple. Its movement does not depend upon variations of pressure, nor can it be abused by the driver. Its action is positive and automatic, and it cannot be tampered with.

The low-pressure steam chest is constructed with a secondary steam chest or chamber, having ports leading to the low-pressure steam chest. Connected to this chamber is a steam pipe passing through the smokebox, and which is connected to the regulator Tee pipe. The opening and closing of the chamber ports are controlled by a valve, which is connected to the reversing shaft of the valve motion. When the reversing lever is in full forward or full back gear, the ports are open and the boiler steam is supplied to the low-pressure steam chest. At this time the low-pressures only are supplying power, whilst the high-pressure pistons simply float in the boiler steam. The low-pressure cylinders being 22 in. diameter, ample power is always obtainable for starting.

The operation of this valve will be more

fully understood by reference to the drawing:—Fig. 1 is the longitudinal section on line *AA*, Fig. 2; Fig. 2 is the sectional plan on line *BB*, Figs. 1 and 3; Fig. 3 transverse section on line *CC*, Figs. 1 and 2; Fig. 4 enlarged elevation from inside of starting valve corresponding to Fig. 1; Fig. 5, sectional plan of same, corresponding to Fig. 2; Fig. 6, transverse section of same, corresponding to Fig. 3.

The low-pressure steam chest *D* is of ordinary construction with receiver pipes, through which steam is admitted from the high-pressure cylinders. Adjacent to the steam chest *D*, a secondary steam chest or chamber *a* is constructed, cast therewith, with ports *N* and $N^1$ communicating with the steam chest.

To the secondary steam chest, or chamber *a*, is connected a steam pipe *m*, passing through the smokebox, which delivers steam to the boiler.

In the secondary steam chest a starting valve is placed capable of sliding to and fro past the ports *N* and $N^1$, so that when in its extreme positions at either end of its stroke the ports *N* and $N^1$ are opened, but in any intermediate positions these ports are closed. This starting valve is operated by a lever connected direct to the reversing shaft.

The starting valve is constructed of two slide valves, *b* and $b^1$, placed back to back, which are pressed to their seats by the pressure of high-pressure steam, but spring *c* and $c^1$ are inserted to insure the valves being always kept to their faces.

These valves are easily examined or removed by taking off the cover *e*. The arrangement is entirely automatic and positive in its action.

From an extensive number of experiments made with the original compound engine and a simple expansion engine of the same type, the compound showed a saving of 25 per cent. of fuel and a corresponding saving in water. The working pressure of both engines in these tests was 180 lb. per sq. in.

Loads as high as 800 tons are hauled daily by these compounds over gradients of 1 in 150.

PARTICULARS OF EIGHT WHEELED COMPOUND GOODS ENGINE WITH "BELPAIRE" FIREBOX.

| | |
|---|---|
| Cylinders, high-pressure ... ... | 15½ in. × 26 in. |
| ,, low-pressure ... ... | 22 in. × 26 in. |
| Wheels, diameter ... ... ... | 4 ft. 6 in. |
| Wheel base ... ... ... ... | 16 ft. 4 in. |
| Centre of leading to driving ... | 5 ft. 11½ in. |
| ,, driving to intermediate | 5 ft. 2½ in. |
| ,, intermediate to trailing | 5 ft. 2¼ in. |

| Weight loaded:— | T. | C. | Q. |
|---|---|---|---|
| Leading wheel ... | 14 | 4 | 3 |
| Driving ,, ... | 15 | 13 | 2 |
| Intermediate ... | 16 | 9 | 1 |
| Trailing ... ... | 14 | 8 | 3 |
| Total ... | 60 | 16 | 1 |

| | |
|---|---|
| Boiler, diameter ... ... ... | 4 ft. 10 in. |
| Length between tube-plates ... | 15 ft. |
| Firebox, length ... ... ... | 8 ft. 1 in. |
| ,, width ... ... ... | 4 ft. 1 in. |
| ,, height ... ... ... | 6 ft. 3⅛ in. |
| Tubes, No. 225, outside diameter | 2 in. |
| Heating surface:— | |
| Tubes ... ... ... ... | 1,767 ft. |
| Firebox ... ... ... ... | 147 ft. |
| Total ... ... | 1,914 ft. |
| Firegrate area ... ... ... | 23 ft. |
| Eight wheeled tender loaded ... | 41 tons 9 cwt |
| Capacity of tank ... ... ... | 3,600 gallons |
| Quantity of coal ... ... ... | 5 tons. |

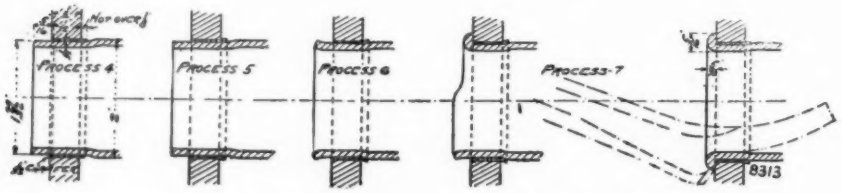



FIG. 1.—METHOD OF SETTING BOILER TUBES, UNION PACIFIC RAILROAD.

1. All scale must be removed from flue hole by small air drill with small emery wheel on shaft of drill.
2. All scale must be removed from end of flue. This can be done by holding a square file on end of flue while being cut to length and flue is revolving.
3. Copper of proper thickness inserted and expanded in flue hole. Edge of copper should be $\frac{1}{32}$ in. from face of flue sheet.
4. Flue inserted and pinned out.
5. Rolled with roller expander.
6. Expanded with Prosser sectional expander.
7. Beaded with standard beading tool.

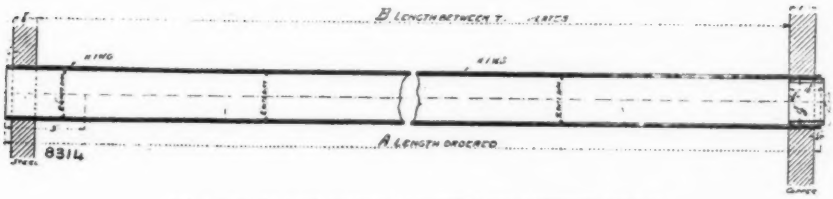



FIG. 2.—BOILER TUBE SETTING, LANCASHIRE AND YORKSHIRE RAILWAY.

## Causes of Leaks in Locomotive Boiler Tubes.

At the fortieth annual convention of the American Railway Master Mechanics' Association a paper was presented by Mr. M. E. Wells on "The Causes of Leaks in Locomotive Boiler Tubes," an abstract of which will be of undoubted interest to readers specially interested in this section.

The subject in hand falls into two broad divisions, viz, leaks due to mechanical causes and those due to temperature variations. Each of these may be sub-divided as under:—

I. *Leaks due to Mechanical Causes.*—A. Defective work at time of first setting of tubes. B. Poor and hasty work in making repairs. C. Vibration of tubes in service. D. Wearing out of tube-ends by abrasive action of cinders.

II. *Leaks due to Variations in Temperature.* — A. Equal variations. B. Unequal variations. (a.) Ingress of cool air. (b.) Deposits of scale. (c.) Varying water temperatures.

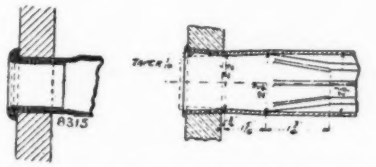



FIG. 3. — BOILER TUBE SETTING OF SOUTHERN RAILWAY OF FRANCE.



FIG. 4. — BOILER TUBE SETTING OF NORTHERN RAILWAY OF FRANCE.

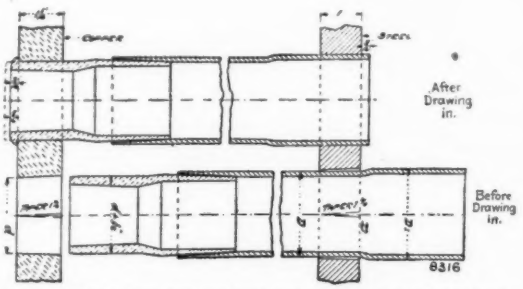



FIG. 5.—BOILER TUBE END AND SAFE END. BAVARIAN STATE RAILROAD.

To secure new information on the subject the author has sent out to the principal railways all over the world a list of questions bearing on leakage causes. Commenting on this letter Mr. Wells says:—

"We made a mistake in saying, in the letters to foreign railways, that the question referred to iron and steel boiler tubes and tube-plates, as we use no other kind in the United States. On account of this a number replied that they could give us no information, since they use only copper for fire-boxes and tube-plates, and, in some cases copper and brass tubes."

Replies received from Great Britain and Europe indicated that copper and brass tubes are in many cases being replaced with those of soft steel. In early cases the steel tubes were reinforced with copper safe-ends at the fire-box tube-plate, but the use of these is being discontinued, and some foreign roads are setting the soft-steel tubes directly into the copper tube-plate.

Some railways, realising that the causes of tube leakage are practically the same, whether the tube-plate be of copper or of steel, sent very full replies. The author states that these recorded causes from abroad were substantially identical with those reported by American roads.

Taking up the causes as they occur in the foregoing outline, and in some cases suggesting remedies for the troubles:—

I. *Leaks due to Mechanical Causes.*—A. Defective work at time of first setting of tubes: This is treated as a very insignificant cause of leakage; in the largest boilers, however, "the most skilful job that it is possible for a skilled mechanic to do on the bottom

tubes in the fire-box will hold, at most, but a few days."

B. Poor and hasty work in making repairs: This is, says the author, a much more prolific source of trouble than any one of the other causes under this main heading. The remedy is, briefly, "take time to do it well."

C. Vibration of tubes in service: That tubes vibrate vertically is substantiated by a case found by the author of a 19 ft. tube set so close to the bottom of the shell that a rivet-head had worn a hole through the tube-wall. Such vibration is not regarded as serious in the way of loosening the very simple tube-settings in the smoke-box tube-plate.

D. Wearing out of tube-ends by abrasive action of cinders: The Northern Railway of France suggested this cause; the Pennsylvania Railroad reports the same or a similar condition, referred to as "burnt-off and cracked heads," due to shallow fire-boxes. Further on in the paper the author says, in regard to a kindred phase of this:

"I want to say a few words about the idea that much of this trouble in line with the fire-door comes from overheating and burning off of the tube ends. In my opinion, there is much misconception on this point. This trouble is the direct result of constantly changing and varying temperatures on the water side."

This throws it into classification II.; and Mr. Wells cites a case to prove his contention:

II. *Leaks due to Variations in Temperature.* —A. Equal variations: The negligible amount of damage done to boiler-tube joints—*i.e.*, tube-ends fitted into a tube-plate—is shown to have been proved experimentally, in a special test involving microscopical examination of a joint alternatively heated to 450° F. and cooled, over a period of 60 days, twice every 24 hours. The conclusion is drawn from this that more than the uniform heating and cooling of a tube is required to loosen it in the plate. This is shown in practice from the fact that the top tubes in a fire-box give practically no trouble from leakage as compared with the bottom tubes, though the former are subjected to higher temperatures; proof of this is cited in tests made by the Chicago Great Western Railway.

B. Unequal variations: This is declared to be the most important division of the subject in hand. The author takes up, first, (a) "the apparent cause of all causes. It is always given, and has been talked about more than all other causes put together. The opinion regarding the importance of this cause is just as strong in Europe as it is in the United States." On this point we may quote the author at length:

"I refer to cold air. The opinion regarding the direful effects of cold air in causing leaks in locomotive boilers is so universal and so strongly held that, were I not so sure of my own position on the subject, I should hesitate to undertake the task of trying to show that its effect is really not very potent to cool boiler tubes and cause leaks.

In answer to one of the questions sent out for information, cold air, as a cause of leakage, is the most universal answer given. In the same list of questions I asked the following 'With tubes and tube plates free of incrustation, can cold air entering the fire-box cool the metal any appreciable amount below the temperature of the water in the boiler?' The majority of the answers to this question is 'No'; and yet every one of the gentlemen so answering has given, in another part of his answers, cold air as a cause of tube leakage. I confess that I anticipated this when the questions were formulated.

If cold air entering a fire-box cannot cool a tube or boiler-plate any appreciable amount below the temperature of the water on the other side, what serious effect can it have in producing unequal variations of temperature, which are the real causes of leaks? In arriving at this conclusion I am fully cognisant of the fact that an incrusted tube or sheet may be slightly cooled, on account of the inability of the heat of the water to get through the scale to the tube or plate. But ordinarily, and with the ordinary scale formation, the cooling on account of cold air is practically harmless as a cause of leaks."

The matter (c) of leaks due to unequal temperature variations in the water space is briefly treated, and attention is called to the injudicious injection of feed-water as a prolific source of trouble. Tests made by the Chicago, Burlington & Quincy Railroad, in this direction, are reported in the 1904 Proceedings of the Association, pp. 231-241. Adequate education of drivers and firemen by the locomotive department, in the potential troubles from this direction, is strongly recommended. The author also advocates, as supplementary betterment, adoption of new methods of feeding and the heating of feed-water. The London and South Western Railway is cited, which passes its feed-water through the smoke-box for heating it; this road reports: "We have little or no trouble with leaky tubes—not such as to require attention between trips."

*Various National Practices in Tube Setting.*—In connection with I-D—wearing out of tube ends by abrasive action of cinders, and kindred causes—a number of sketches are given in Mr. Wells' paper showing the methods of tube setting reported by various countries. These will be of interest by way of comparison.

Fig. 1 shows the process employed in this country by the Union Pacific Railroad, practically the United States standard process.

Fig. 2 is a drawing sent by the Lancashire & Yorkshire Railway, showing the tube and ferrule at the fire-box end; the ferrules are welded, and of Swedish high-carbon steel—those of solid-drawn weldless tubing having been found too soft. The ferrules are driven in with an ordinary shift. The fire-box tube plate is 1-in. copper, and the front tube-plate $\frac{7}{8}$-in. steel. This railway does not bead over the tube-end, while the North Eastern Railway of England does.

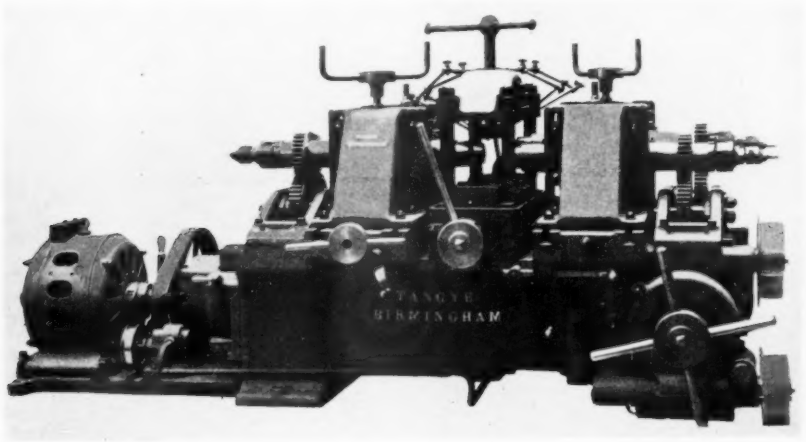
Fig. 3 shows a tube-end as treated by the Southern Railway of France, which rolls and beads over the end and then puts in a ferrule. The sketch shows a ferrule with a head or collar, which is sometimes used when ferrules are replaced.

The Northern Railway of France uses tubes of soft steel, 77 mm. (2·75 ins.) in diameter, swaged to 66 mm. (2·6 ins.) and rolled and beaded into the copper plate, as shown in Fig. 4. The Royal Bavarian States Railroad employs a copper safe-end on an iron tube (Fig. 5). It is merely rolled and beaded in the fire-box, and only rolled in the front end. Attention is directed to the increased strength of the safe-end, and the avoidance of shimming at the front end.

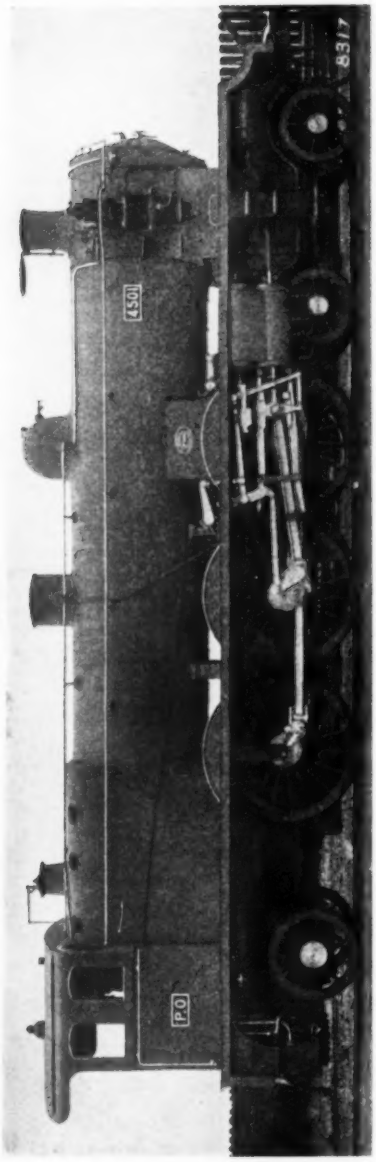
## Machine for Drilling Rails.

The accompanying illustration is that of a special machine made for drilling rails, driven by electric motor, constructed by Messrs. Tangyes, Ltd., of Birmingham.

The machine has four spindles, two on each side, so that the holes can be drilled from either side; and it is provided with three speeds, so that holes varying from $\frac{3}{4}$ in. to $1\frac{1}{4}$ in. diameter may be drilled. The machine has a strong massive bed on which is bolted a cross slide having a table 12 in. wide by 26 in. long, with a cross adjustment of 3 ins. The table is provided with bolts carrying a plate having lock bolts for clamping the rail to the table. On each side of the table is a saddle carried on the bed, on which the saddle is free to slide along. Each saddle has two uprights on its face, these being carried on a slide having a large steel spindle running in hard gun-metal bearings. Each spindle has a hole bored through, and is provided with a special thrust arrangement and provision for setting the drill. Each spindle head has a vertical adjustment, and each upright can be moved in or out independently of each other, so as to allow




MACHINE FOR DRILLING RAILS.




4-6-2 "PACIFIC" TYPE LOCOMOTIVE: PARIS-ORLEANS RAILWAY.

holes of 14 in. maximum and 7 in. minimum centres to be drilled.

The spindles are provided with a cone arrangement for holding the drills so that the latter can be taken from the back of the spindle, or in case of short drills, the saddle can be run back, and the drills taken out from the front. Each saddle has a self-acting feed motion, and stop motion is provided by means of a drop-out worm worked from a hand lever and rod connected to the right-hand saddle. One set of headstocks may be worked at a time if so desired, and the two sets are arranged so that they can be adjusted together.

Provision for elongating the holes is made by means of the lever shown in front of the table. The bed is made into a trough, and a pump for supplying lubricant to the work is provided. All the gearing is machine cut from the solid.

## 4-6-2 "Pacific" Type Locomotive—Paris-Orleans Railway.

The latest Continental development in locomotive practice is the adoption, by the Paris-Orleans Railway, of the "Pacific" or 4-6-2 type of engine, twenty of which are now being constructed for that company by the Société Alsacienne de Constructions Mecaniques, Belfort.

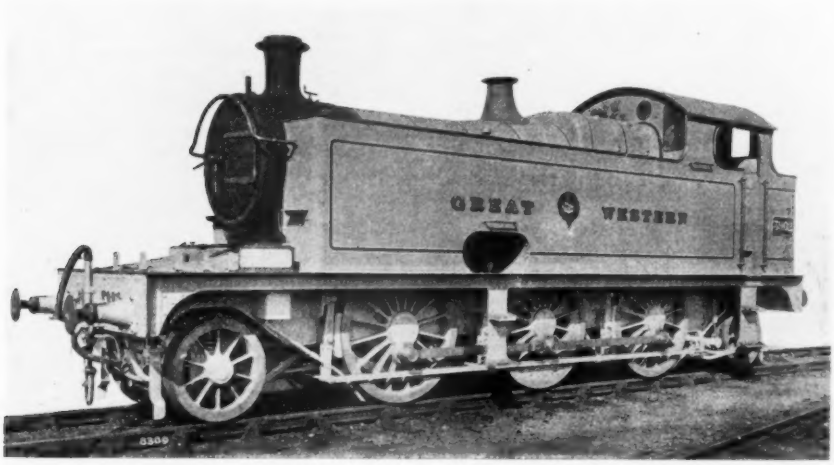
The placing in service of this type of engine marks an important advance in that this is the first appearance of their kind on a Continental railway. As will be realised by a study of the dimensions, these locomotives are of great power and have already demonstrated their ability to haul the heaviest expresses of the Paris-Orleans line up long and trying gradients at a speed approximating to forty miles per hour. The increased capacity of this type is due to the adoption of a wide firebox, with a grate area of 46 sq. ft.; a large heating surface proportional to the grate area aggregating 3,040 sq. ft., and an increase in the adhesive weight rendered possible by the six-coupled wheel arrangement. As in the case of the "Atlantic" (4-4-2) type the possibility of using the wide firebox constitutes the principal advantage possessed by the "Pacific" type of locomotive over those of the 4-4-0 and 4-6-0 class in which firebox dimensions are restricted by the rear coupled axle.

The new engines are compounded on the "De Glehn" system, in which the low-pressure cylinders are placed inside and

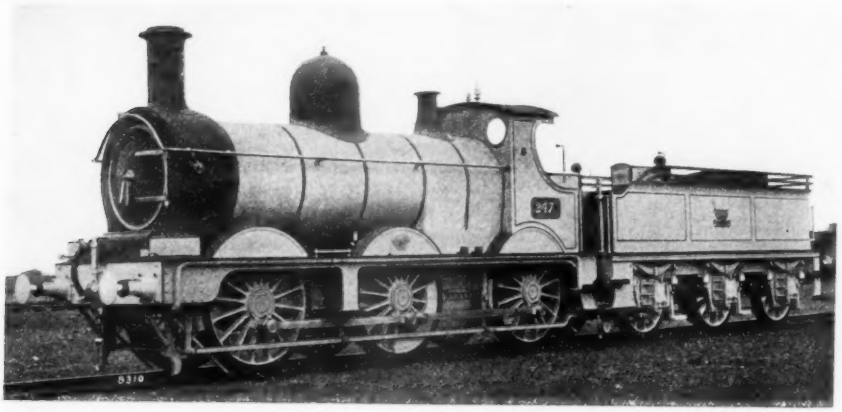
drive the leading pair of coupled wheels, while the high-pressure cylinders are outside and drive the middle pair.

Piston valves with internal admission passages distribute steam to the high-pressure cylinders, the valve gear following the usual arrangement. Other points to be noted are that the bogie is braked and that the "Westinghouse" high-speed brake has been fitted. The following are the leading dimensions:—

| | |
|---|---|
| Diameter of cylinders, h.p. ... ... | 15½ in. |
| ,, ,, l.p. ... ... | 25½ in. |
| Piston stroke ... ... ... | 26 in. |
| Coupled wheels, diameter ... ... | 5 ft. 10 in. |
| Bogie wheels, diameter ... ... | 3 ft. 3 in. |
| Trailing wheels, diameter ... ... | 3 ft. 10 in. |
| Boiler, diameter... ... ... ... | 5 ft. 7 in. |
| Working pressure ... ... ... | 227 lb. per sq. in. |
| Tubes, number ... ... ... ... | 261 |




2-6-2 TYPE TANK ENGINE REBUILT FROM A 0-6-0 TYPE GOODS ENGINE, GREAT WESTERN RAILWAY.



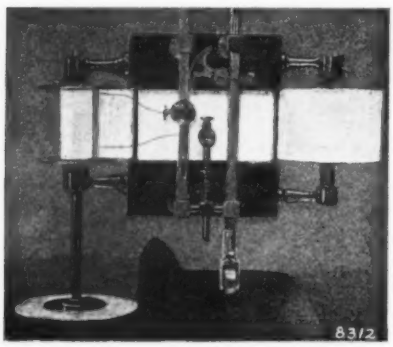

THE SIX-COUPLED GOODS ENGINE BEFORE CONVERSION TO A 2-6-2 TYPE TANK ENGINE.

| | |
|---|---|
| Heating surface, tubes... ... ... | 2,612 sq. ft. |
| ,, ,, fire-box ... ... | 167 sq. ft. |
| Total ... ... ... | 2,779 sq. ft. |
| Water-exposed surface ... ... | 3,040 sq. ft. |
| Grate area ... ... ... ... | 46 sq. ft. |
| Engine, weight (empty) ... ... | 82 tons. |
| ,, ,, (working order) ... | 90 tons 10 cwt. |
| ,, ,, (available for adhesion) ... ... | 54 tons. |
| Engine, length over buffers ... ... | 44 ft. |
| ,, maximum width ... ... | 8 ft. 2 in. |

## Converted Goods Locomotive: Great Western Railway.

An interesting conversion of a 0-6-0 type goods locomotive to a 2-6-2 type tank engine has recently been carried out at the Swindon shops of the Great Western Railway, the engine in its original state, and as it appears when rebuilt, being shown in the accompanying half-tone illustrations. The object of the conversion is not far to seek. The increasing length and weight of goods trains called for a more powerful design of locomotive than that represented by the 0-6-0 type and led to the introduction of the "Mogul," or 2-6-0 type, and the "Consolidation" or 2-8-0 type, leaving the Company in possession of a number of the older pattern locomotives still in first-class working condition. As will be seen from the illustration, they possess the general characteristics of the six-coupled goods type, viz., inside cylinders driving on to the cranked axle of the middle pair of wheels; "Stephenson" valve gear and cylindrical boiler of the ordinary pattern with round-topped fire-box. Within the limits of their power the type is useful enough, and as rebuilt in tank form will prove a useful addition to the Company's stock of suburban and local passenger engines, to say nothing of their utility as short-distance goods engines. As will be seen, the old boiler has been replaced by one of the coned type, fitted with a "Belpaire" fire-box, while the frames have been lengthened to accommodate a coal bunker and pony trucks. Side tanks have also been added for the water supply. These, it will be noted, extend well forward to the smoke box, facilities for reaching the motion being afforded by suitable openings. The following are the leading particulars of the engine before and after rebuilding:—

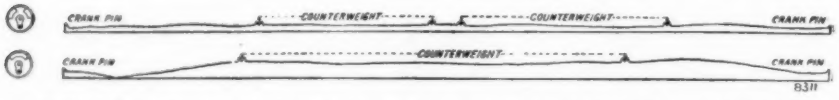
| | Original Engine. | As rebuilt. |
|---|---|---|
| Cylinders, diameter ... | 17 in. | 17½ in. |
| Piston stroke ... ... | 24 in. | 24 in. |
| Steam ports ... ... | 15 in. by 1⅞ in. | 16 in. by 1½ in. |
| Exhaust ports ... ... | 15 in. by 4 in. | 16 in. by 2⅝ in. |
| Pony truck wheels, diameter ... ... | ... ... | 3 ft. 2 in. |
| Coupled wheels ... ... | 5 ft. 2 in. | 5 ft. 2 in. |
| Wheel-base, coupled ... | 15 ft. 6 in. | 14 ft. |
| ,, engine ... | 15 ft. 6 in. | 28 ft. |
| Boiler, diameter outside front ring ... ... | 4 ft. 4½ in. | 4 ft. 2 in. |
| Boiler, diameter outside back ring ... ... | 4 ft. 5 in. | 4 ft. 9⅛ in |
| Boiler, length of barrel | 10 ft. 3in. | 10 ft. 6 in |
| Fire-box (outside) ... | 5 ft. 4 in. by 4 ft. | 5 ft. 10 in. by 5 ft. |
| Tubes, number ... ... | 249 | 255 |
| ,, diameter... ... | 1¾ in. | 1⅝ in. |
| ,, length ... ... | 10 ft. 6½ in. | 10 ft. 10⅛ in. |
| Heating surface, tubes... | 1,200 sq. ft. | 1,178·01 sq. ft. |
| ,, ,, fire-box | 107·72 ,, | 93·85 ,, |
| Total ... | 1,307·72 sq. ft. | 1,271·86 sq. ft. |
| Grate area ... ... | 17·33 sq. ft. | 16·6 sq. ft. |
| Working pressure ... | 150 lb. | 200 lb. |
| Tractive effort ... ... | 15,102 lb. | 21,339 lb. |
| Water capacity of tender or tank ... ... ... | 3,000 galls. | 1,500 galls. |
| Weight of engine in working order... .. | 36 tons 12 cwt. | 62 tons 4 cwt. |
| Weight on coupled wheels ... ... ... | 36 ,, 12 ,, | 47 ,, 19 ,, |




APPARATUS FOR RECORDING UNEVEN TYRE WEAR.

## Apparatus for Recording Uneven Tyre Wear.

An interesting investigation has recently been carried out on the Colorado and




DIAGRAMS TAKEN WITH THE ABOVE APPARATUS SHOWING THE EFFECT OF TWO FORMS OF COUNTER-WEIGHTS.

Southern Railway in connection with uneven tyre wear on locomotive driving wheels. A recording apparatus was employed of the form shown in the accompanying illustration by means of which a line corresponding to the contour of the tyres is transferred to a strip of paper, the line varying from a datum line by an amount corresponding to the variation of the tyre from a true circle. A flat, for example would be indicated by the approach of the contour line to the datum line.

The apparatus is held in position adjacent to the periphery of the driving wheel with the outside edge of which a disc connected with the paper winding spool is in frictional contact thus causing the paper to travel over the table. On the latter the record is made by pencils clamped in sliding bars. Another roller bears against the tyre face of the driving wheel and operates the sliding bars holding the pencils. The amplitude of the vibrations of the bars naturally varies with the inequalities in the tyre. One of the sliding bars is toothed and meshes with a pivoted segmental wheel arranged in a manner such that the small vibratory movements of the first sliding bar will magnify those of a second which also carries a pencil. Two records are therefore obtained in one of which the curve corresponding to the tyre inequalities is greater than the other and is recorded in direction vertically opposite. According to the *Scientific American* these diagrams show that the tyre wear is greatest in the neighbourhood of the greatest weight in the wheel. Thus, if the crank-pin and balance weight were of unequal weight the wear would be greater adjacent to the crank-pin, and *vice versa*. Whenever excessive wear was recorded the wheels were reweighted and balanced, and the disparity of weights corrected. In one case a high-speed passenger engine was found to be 230 lbs. too light in the counter-balance, and several from 50 lbs. to 150 lbs; this unbalanced weight being carried along at from 80 to 100 feet per second, was expected to run smoothly.

One class of engines was found which produced practically parallel lines on the records, and they were balanced by the "Davis" method of using two counter-weights to each driving wheel the weights placed 120 degrees apart, and forming, with the crank-pin centre, an equilateral triangle.

The upper of the two diagrams shows a more even movement than the lower one. The upper diagram represents the affect of balancing the counter-weights by the "Davis" method, which shows a fairly even line throughout. The lower diagram shows the common method of arranging the counter-weight opposite the crank, and it will be seen the depression in the record line is very marked opposite the crank-pin. The position of the counter-weights is shown in the small circles at the end of each diagram.

# ELECTRICAL NOTES.

*By ANDREW STEWART, A.M.I.E.E.*

## The Use of Exhaust Steam Turbines.

We have several times given details of exhaust steam turbine installations, and of the economies resulting from their use. The system is being pushed among colliery and steelworks engineers by the Waste Heat and Power Co. of Newcastle-on-Tyne, and the results have been very encouraging. This firm have recently placed an order with Messrs. Willans and Robinson for two turbo generators to give 1,350 k.w. each, when running at a speed of 2,400 revs. per min. These turbines, which will be installed at Sir B. Samuelson & Co.'s works, near Middlesbrough, use the exhaust steam from the blowing engines at 2 to 3 lbs. per sq. in. above the atmospheric pressure, and exhaust to condensers of special design giving a vacuum of 29 ins.

These are the largest exhaust steam turbines which have been constructed in this country, and the unique feature of the installation is that all the steam exhausted from the blowing engines will be condensed, whether used by the turbines or not. This involves a special arrangement of bye-passes.

A similar, but smaller plant, of 500 k.w. is being built for a Staffordshire ironworks, while two sets of 1,000 k.w. each are being built for the Oakdale Colliery of the Tredegar Iron Works, South Wales, but in this case some important modifications have been introduced. The turbines will work with exhaust steam from the winding engines during the day. At night, when the winding plant is not in frequent operation, the turbines will work with "live" steam direct from the boilers. Hitherto when it was necessary to operate these exhaust steam turbines with live steam, a reducing valve was introduced between the boilers and the turbine, but by the use of special valves, and a modification in design, Messrs. Willans and Robinson have made the turbine very easily adapted to the dual service, thus marking one of the most important improvements in this class of work since the exhaust steam turbine was introduced.

## Breakdowns and Accidents with Electrical Machinery and Apparatus.

The reliability and safety of the service rendered by the electrical equipment is of very great importance to the works owner. Interruptions in the service often cost a very considerable amount in indirect expenses for, apart from the direct cost of the repair, there is the stoppage of a considerable amount of productive machinery; when accidents occur, such as shocks more or less severe, there is the disinclination of the workman to come to close quarters with electrically operated apparatus, and this factor often leads to the failure of such appliances when success might be achieved.

It is gratifying to learn from the last annual report of the British Engine, Boiler and Electrical Insurance Co. that breakdowns of electrical machinery are becoming less frequent, while our esteemed contemporary, *The Electrical Review*, provides some data on fatal electric shocks during the last two years, which are instructive, inasmuch as they indicate in what direction trouble is likely to be expected with an electrical installation.

Dealing first with the insurance company's report, it appears that a breakdown occurred with one in every 8·2 motors insured. As in previous years, armatures and rotors (the rotating part of an alternating current motor) account for about half of all the breakdowns, while the commutator and brush gear provide nearly a quarter of the trouble, leaving about 25 per cent. of all troubles to miscellaneous occurrences, and failure of the field coils, or stators of induction motors; the two latter account for 11 per cent. of the dynamo, and 14 per cent. of the motor failures.

It is worthy of note that the rate of breakdown was twice as high with direct current machinery as with alternating, but the cost of repair in the case of direct current machines was only half. This is due to the fact that when an alternate current motor breaks down, the destruction of the windings is generally much more complete than with a direct current machine; moreover, there are fewer small details likely to give trouble in an alternating current machine. These same details contribute a not inconsiderable number of accidents to the total for the direct current motor.

Neglect in one form or another is a fruitful source of breakdown, and dirty motors seem as liable to more or less serious breakdown as dirty people. A deposit of carbon dust and oil on the windings makes breakdown in the early future an absolute certainty.

The data available *re* fatal accidents from shock in connection with electrical installations is no less interesting. It appears that thirty-seven fatal accidents have occurred in two years, fourteen of

the victims being electricians or electrical engineers in the exercise of their duties, and twenty-two were workmen in other industries who accidentally, or when trespassing, received a shock.

Most of the electrical men died from high pressure shocks, viz., 1,000 to 11,000 volts, though in one case, that of a lamp trimmer at the Patent Shaft and Axletree Works, Wednesbury, a youth, aged eighteen, appears to have been killed by a 200-volt shock. It is most unusual for such shocks to prove fatal, and when this is the case, other troubles such as low general health, or heart trouble is found to have been an important factor in the result.

The twenty-one workmen who were not directly connected with the electrical industry were in a number of cases employed in mines and had accidentally touched a live wire, or fitting, or had come in contact with steel structural work or haulage rope which had accidentally become alive ; these accounted for almost half of the deaths of workmen who were not electricians. Most of these fatalities were with currents of 500 volts or over, but a blacksmith at Acklam Iron Works, Middlesbrough, was killed when handling an iron plate which had come into contact with a wire at a pressure of 250 volts, while a workman in an engineer's shop in Sheffield was also killed with a shock from a low pressure circuit, the result of a practical joke by his fellow workmen, who connected the lighting circuit to a door handle which deceased attempted to turn. In this case the victim was in bad health, but a butcher aged twenty-one in good health was killed through touching a defective fan switch. It appears, however, that he was working in a pork-pickling cellar, and his clothes and boots were saturated with brine, so that although the pressure was low, only 200 volts, the conditions were very favourable to the passage of a considerable amount of current.

It must not be forgotten that when conditions are favourable, low pressures may prove fatal, even if the victim is in good health, for it is the amount of current which passes through the system which causes serious or fatal results. Ordinarily a very high pressure is necessary to force sufficient current through the human body to cause suspension of the natural functions of the vital organs, but if the boots or clothes are wet, or the victim is sweating, the contact resistance of the body is so reduced that a good deal of current may pass even at 200 volts. Many electrical men appreciate the difference in the violence of the shocks which they receive when their hands are moist with sweat, and when their hands are quite dry. People with soft hands suffer severely from pressures which more horny handed sons of toil scarcely feel.

As an example of this, the writer remembers a number of experiments to ascertain the absolute immunity of many animals from electric shock. These experiments were suggested by the fact that a cat used to sit purring on the 5,000 volt terminals of a transformer, the transformer being the only warm place in the sub-station. A white mouse was the chosen victim, and it ran across two plates having a difference of potential of 5,000 volts apparently without inconvenience. After it had been dipped in water it was again allowed to run over the plates, but nothing remained but a few charred bones. It is clear, therefore, that a dangerous or fatal pressure is difficult to define. Much depends on circumstances, and while pressures of 200 to 400 volts are seldom fatal to human beings, one need not assume that they are perfectly safe.

## Recent Developments in Swedish State Railway Electrification.

About eighteen months ago we devoted a good deal of space to a description of the plant made in England and abroad for the experimental work in connection with the above. Little further has appeared in the English press, but we learn from German sources that very considerable progress is being made with

the electrification scheme for the entire State railways in southern Sweden, which extend to 1,300 miles. The Government have recently purchased three waterfalls, one giving 9,000, another 12,000, and the third 36,000 h.p., a total of 57,000 h.p. Five hydro-electric power stations are proposed, but three only have been acquired. To cope with the estimated traffic in 1920, two additional stations are proposed, but as all the available water power plants have been acquired, it is proposed to put down steam stations, using peat as fuel.

The estimated cost of this scheme, based on the present traffic, is for the generating plant, £1,200,000; for transmission lines and sub-stations, £1,800,000; a total of £3,000,000, exclusive of rolling stock. It is estimated that by 1920 the traffic will be about 60 per cent. greater than it now is, and to cope with this the capitalisation of the power stations will be increased to £1,400,000, and the line and sub-stations £2,400,000, a total of £3,800,000. The estimated saving on the present traffic expenses is £2,000 per annum, but by 1920 the saving due to electric traction is estimated at £74,000 per annum.

The electrical energy will be transmitted at a pressure of 50,000 volts to 37 sub-stations, where it will be reduced to 15,000 volts, which, as we have already indicated when describing the experimental plant, is the trolley wire pressure. All the new trains are heated electrically, this method having proved more economical owing to the low cost of electrical energy.

# IRON, STEEL, AND THE FOUNDRY.

*Conducted by PERCY LONGMUIR.*

**The Modern American Blast Furnace.***—In this article, the first of a series, Professor Bradley Stoughton describes in general terms the equipment of the American Blast Furnace. In modern plants chief attention is paid to devices for handling material and charging the furnace with the object of saving time; ensuring continuous working at full capacity, and of eliminating manual labour as far as possible. Behind the blast furnace are situated two long rows of storage bins, one of which is shown in elevation in Fig. 1. These bins are filled by bottom dumping cars which bring the ore to the furnaces; similar methods of storage are also adopted for limestone and fuel. Between and under the two rows of bins runs a track on which buggies are transferred back and forth, being first filled with a weighed amount of ore, limestone or fuel, and then switched into a position where they can deposit their contents into the loading skip of the blast furnace. Charging is effected entirely by mechanism operated and controlled from the floor level, as in Fig. 1. A double inclined skipway extends above the top of the furnace, one skip discharges into the hopper, whilst the second skip is at the bottom of the incline ready to be loaded with its charge. The upper hopper of the furnace is closed at the bottom by an iron "bell," which is pressed up against the bottom of the hopper by a counterweight, but may be lowered by operating the cylinder,

* *The Engineering and Mining Journal.*

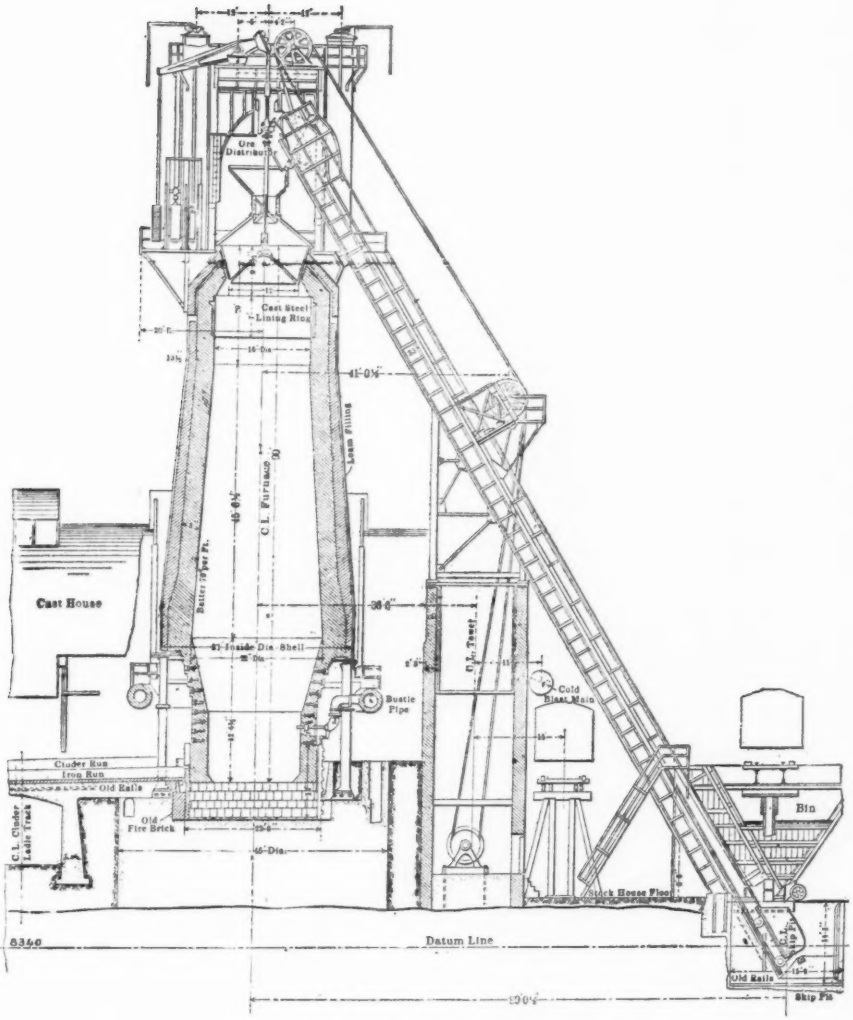



FIG. I.—SECTION OF BLAST FURNACE AND MATERIAL HOIST.

shown at the side, to allow the charge to fall into the true hopper of the furnace. In this way the true hopper is progressively filled with ore, flux and fuel. This hopper is also closed by means of a bell actuated from the floor level. At intervals the bell is lowered and the contents of the hopper allowed to fall in an annular stream on top of the material already in the furnace. The double bell permits of charging without the escape of gas.

Professor Stoughton then passes on to a description of the furnace and accessories, the chief features of which are, however, clearly shown in the illustration Fig. 1. Waste gases are led through the downcomer, passed through a dust catcher, and then on to the hot blast stoves or the power producer. If burned under boilers the available gas will generate enough power to operate the blowing engines, hoisting mechanism, and other machinery used in connection with the furnace. At several plants the gas available for power is cleaned and utilised in gas engines, whereby much more power is obtained, the excess over that necessary to furnish blast and the mechanical requirements of the furnace being usually converted into electricity and transmitted to more distant points.

**The Chemistry of the Blast Furnace.***—In the second article Professor Stoughton deals at some length with the reactions of the blast furnace. On charging the ore two reactions begin to take place between it and the ascending gases:—

(1) $2\,Fe_2\,O_3 + 8\,Co = 7\,Co_2 + 4\,Fe + C.$

(2) $2\,Fe_2\,O_3 + Co = 2\,Fe\,O + Fe_2\,O_3 + Co_2.$

The carbon formed by reaction (1) is deposited in a form similar to lamp black, but this reaction is in turn opposed by two reactions with carbon dioxide gas:—

(3) $Fe + Co_2 = Fe\,O + Co.$

(4) $C + Co_2 = 2\,Co.$

Reaction (3) begins at about 575° F., and (4) begins at a temperature of about 1,000° F., or about 20 ft. below the stock line. Reaction (4) is so rapid that the deposition of carbon ceases at a temperature of 1,100° F. Practically all the iron is reduced to a spongy metallic form by the time a temperature of 1,475° F. is reached. This is about 45 ft. from the stock line and less than 30 ft. above the tuyeres. At 1,475° F., the decomposition of the limestone commences, and only *Ca O* reaches the smelting zone. On reaching the smelting zone the iron melts and trickles through the column of coke from which it completes its saturation with carbon. At a corresponding point the lime unites with the coke ash, and the impurities in the iron ore forming a fusible slag which also trickles down and collects in the hearth. During this transit different impurities are reduced by carbon, and the extent of this reduction determines the characteristics of the pig iron, for reduced elements are dissolved by the metal, while those in the oxidised form are dissolved by the slag. Only one exception occurs, namely, that iron will dissolve its own sulphide, and to a less extent that of manganese, but not that of other metals, as, for instance, *Ca S*.

There is always a large amount of silica present in the coke ash and some of this is reduced as follows:—

$$Si\,O_2 + 2\,C = Si + 2\,Co.$$

The extent of this reduction will depend on the length of time the iron takes in passing through the smelting zone, the relative intensity of the reducing influence and the avidity with which the slag takes up silica. A higher temperature in the smelting zone, which increases disproportionately the avidity of carbon for oxygen, will promote the reduction of silica. Higher temperatures may be produced by supplying hotter blast or by means of a larger proportion of coke to burden. A basic slag, because of its avidity for silica, will oppose the reduction of silica and is one of the chief means of making low silicon pig iron.

Sulphur enters the furnace chiefly through the coke, in which it may be present as iron monosulphide, *Fe S*, or

* *The Engineering and Mining Journal.*

as iron pyrites, $Fe\,S_2$. Pyrites loses one atom of sulphur near the top of the furnace and becomes $Fe\,S$, in which form it will dissolve in the iron unless converted to sulphide of calcium, $Ca\,S$, which passes into the slag. The intense reduction, which increases the silicon in the iron, has the contrary effect on the sulphur, and this explains the common observation that iron high in silicon is liable to be low in sulphur.

Manganese is reduced as follows:—

$$Mn\,O_2 + 2\,C = Mn + 2\,Co.$$

The amount of manganese in the iron depends to some extent on the character of the ores charged, but it may be controlled somewhat by the character of the slag, because an acid slag will carry a large amount of manganese away in the form of silicate of manganese.

With a certain unimportant qualification, the amount of phosphorus in the iron is controlled by the character of the ores used and districts having high phosphoric ores must make high phosphorus irons.

**The Operation of the Blast Furnace.***—In the third article Professor Stoughton deals to some extent with the actual working of a blast furnace. At the outset, in discussing Gayley's invention of desiccated blast, it is shown that the good results are due to greater regularity in working in addition to the saving effected in fuel. In this respect the fuel economies are so great that the results when first published were received with scepticism. However, J. E. Johnson has explained this saving by showing that every blast furnace has a certain "critical temperature" below which it will not perform any smelting, and that the theoretical temperature of combustion of the smelting zone is only a little above this critical temperature. To increase the interval between the two therefore greatly increases the "available heat" though the change in nominal temperature be small.

After discussing the disposal of slag and iron the writer passes on to a consideration of irregularities in working. The blast furnace is by no means a perfect machine, and difficulties arise in working the furnace and in maintaining a uniform grade of product. Localised chilling of the semi-molten product is responsible for many of these difficulties. This is most liable to happen in the upper part of the smelting zone, where a lump of pasty material may attach itself to the walls of the furnace. This has the effect of retarding the descent of the charge and of deflecting the hot gases to other parts of the furnace. When the furnace is working badly, these scaffolds may occur at two or more places at the same time and cantilever out towards the middle. This will cause the charge to "hang" and may become so bad as to cause a complete arch over the smelting zone, through which it is impossible to drive the blast. Scaffolds may be broken down by suddenly cutting off the blast pressure and allowing the full weight of the charge to come upon the obstruction, in other cases it may be necessary to cut a hole through the wall of the furnace and melt down the obstruction with an oil or gas blow pipe. Scaffolding and hanging are more liable to happen when the charges consist largely of earthy Mesabi ores and in this type of practice localised hanging and slips are not infrequent. When the slip is extensive and a large amount of material is suddenly precipitated into the hearth, the upward rush of gases resembles an explosion inside the furnace and may damage the charging apparatus or throw part of the stock out of the top of the furnace. Some furnaces are fitted with explosion doors which fly open under pressure and relieve the strain whilst the practice in other instances is to fasten everything down as tight as possible and prevent the rapid escape of the gases. The bad work of a furnace is often cumulative in its effect, because irregularities in the smelting zone have an effect upon the top gases, which in turn derange the work of the stoves and hence the hot blast. Irregularities in smelting have a disturbing effect on the

* *The Engineering and Mining Journal.*

grade of iron made and the changes sometimes come suddenly and without warning. For instance a sudden precipitation of cold material into the hearth will chill the smelting zone and cause the silicon in the iron to be low and the sulphur to be high. A similar effect will be produced by the leakage of several gallons of water into the hearth through the burning out of a tuyere or the cooling ring of one of the tuyeres.

**Charginga Modern Blast Furnace.*** --In this the fourth article Professor Stoughton gives methods of calculating blast furnace charges and incidentally touches on the dimensions of furnaces, noting that the size of a modern furnace is limited by the conditions of its work. The hearth may not be more than 15 ft. in diameter or the blast will not be distributed evenly to the centre. The batter of the bosh walls cannot be much more nor less than a certain amount, because they must give support to the charge above and yet allow the solid coke to slip down. The height of bosh is limited because its top must be practically the same as the top of the smelting zone, that is no solid material except coke should descend into the bosh. These conditions limit the diameter of the top of the bosh to not much more than 22 ft. From the bosh the stack walls must decrease in diameter upwards in order that the descending charge, which swells owing to the reactions taking place, shall not become wedged in the stack. The throat must have a sufficiently large diameter to allow of proper charging and this limits the height of the stack. Modern furnaces are therefore usually built about 90 ft. in height and an increase above that limit has resulted in some cases in a decrease rather than an increase of fuel economy.

**The "Gayley" Dry Blast.***—An excellent record was made at the Isabella furnaces of the Carnegie Steel Company with the "Gayley" dry blast in May. A comparison of the work of No. 1 furnace working with desiccated air, and of No. 2 furnace blown with natural air, both using the same materials, shows the following results:—

| | Daily Product. | Coke Consumption. |
|---|---|---|
| No. 1, dry air | 459 tons | 2,029 lbs. |
| No. 2, natural air | 351 tons | 2,372 lbs. |

This shows the average product to be greater per day by 108 tons or 30·7 per cent. with the dry air blast than with natural air and the fuel consumption to be 343 lbs. per ton, 14·4 per cent. lower. The good results obtained with the furnace blown with dry air have been achieved in spite of its bad condition, it being in need of relining, having now produced nearly 612,000 tons of pig iron on one lining.

**Training Apprentices in Foundry work.**†—Of the many perplexing problems confronting American foundrymen none has proved more difficult of solution than the training of apprentices. The demand for skilled moulders in recent years has been greater than the supply and few if any of the trade schools have thus far produced mechanics of sufficient ability to command journeymen's wages. A system of training followed in the foundry of the Ingersoll-Rand Company at Phillipsburg, New Jersey, is stated to have produced excellent results. The foundry equipped with four cupolas has an average daily output of 100 tons of intricate castings, dry sand work predominating. The cores of practically all of the sections are complicated yet the losses are considerably below normal. This is the more surprising in view of the fact that many of the moulders are still in their "teens." The boys commence first in the core room, the tutor being a boy of not less than three months' service and the first duties being comparatively light. The pair work together for three months when the one most advanced progresses to the side of another who has probably worked for nine months, and the three months apprentice is charged with the duty of leading another through his first

* *The Engineering and Mining Journal.*

† *The Iron Trade Review*

steps. This procedure is followed until the end of the first year, when the boy passes from the core department and his payment is increased from $1·00 to $1·25 per day. Before passing on to the moulding floor three weeks are spent on the cupolas, and as a result every moulder has some knowledge of cupola work. When first put on the moulding floor the boy is made assistant to another slightly more advanced. The mode of progression followed in the core room applies to the moulding floors, and with the third year the daily wages are increased to $1·75. At this period many of the boys have the equipment of the average moulder and are permitted to make those sections for which they are most fitted. During the fourth year many of the apprentices are paid the same wages as the skilled mechanics, as the question of stipend is governed alone by their ability. Under this system the company have trained practically all their own moulders.

# The Engineering Exhibition at Olympia.

*I.*

THE Second International Engineering and Machinery Exhibition held at Olympia, was opened on the 19th ult., by Sir Alexander Kennedy, LL.D., F.R.S., under circumstances which pointed to a successful culmination of the efforts of the advisory committee and the organising managers, Messrs. Smith & Bridges, with whom THE ENGINEERING REVIEW has been in active co-operation in their specially appointed official capacity, and to whose efforts the improved representative character of the show is largely due.

After a week's run there is every indication of the financial success of the show, as, although visitors have not been too numerous, the majority of them have been up for business, and the reports of exhibitors show that orders are being placed and inquiries are promising.

Some firms are exhibiting with a collection of machinery representing between 2,600 and 3,000 tons of a value roughly about £100,000. This is an improvement on the figures of last year's exhibition, in addition to which the present is certainly a more generally representative show. Machine tools, however, as before, form the characteristic feature, the collection forming one of the finest that has ever been gathered together under one roof. Not that anything strikingly new is discoverable in this section, the line of development appearing rather to be in the direction of extending and improving existing designs. The show of steam engines is certainly poor; moreover, not one example is shown running. The absence of a steam turbine is certainly a conspicuous fact, as is also the paucity of electrical exhibits. It is quite possible, though, that the probability of a wholly electrical exhibition in the Manchester district being held next year may account for the latter. Of steam fittings and accessories, friction reducing materials and appliances, there is an abundance; and the wood-working and gas engine departments may be said to be well represented. Air compressors and pneumatic tools, too, are well in evidence, a sign doubtless of the increasing popularity of these appliances.

From the point of view of novelty, there are several exhibits which attract much attention, chief among which is perhaps the "Pittler" universal rotary machine. Many have been the attempts to solve the problem of the rotary engine, with what success our readers are only too well aware. Nevertheless, this has not hindered Herr Pittler, of universal lathe fame, from attempting a solution, with the result that he has produced a machine which it is claimed works equally well and efficiently as a steam engine, hydraulic pump, motor, air compressor, air motor, vacuum pump. The machine is shown running in various applications, among which may be mentioned a hydraulic transmission for motor cars. We shall deal in detail with the machine in our

Olympia Number. Another novelty is to be seen on the stand of Messrs. Bullivant & Co., Ltd., in the shape of a working model of a mono-railway. The car, which runs on a steel wire rope, is constructed of two wheels connected by pivots to the extremities of a central light frame-work. The latter is formed of the levers that operate the brake. The load is carried under four arms suspended by steel wire ropes from an upright arm whose base is the brake block itself; therefore the pressure of the brake is always in proportion to the weight of the load that is to be carried.

Another clever invention is the "Barlow" lift gear for lifts working between two floors only, of which a model is shown. No overrunning is possible, and only a minimum of power is required at the beginning of the movement. Broadly, the invention consists of a crank driven by a motor through a connecting rod operating a multiplying gear in such a way that each complete traverse of the latter, and therefore of the cage, is effected by a simple harmonic motion which produces slow stopping and starting independently of the rate at which the motor is running. The "Smith" slotting machine is also shown. It operates on a new principle, an account of which was given in our last issue. Mention may also be made of the "Margewood" lock and an automatic cashier which automatically delivers any required amount from one penny up to five pounds. A clever and ingenious variable delivery 3-throw pump at the stand of Messrs. Thwaites Bros., is worth examination. It is so arranged that its delivery can be varied from nothing to full duty whilst running without alteration to the length of stroke or efficiency, a result obtained by controlling the suction valves. An entirely new method of applying oil or grease to tub axles is shown by the Falcon Iron Works, Ltd., and a new departure in tool-hardening furnaces forms the chief feature at the stand of the British Gas Furnace & Tool Co., Ltd.

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Alldays & Onions Pneumatic Eng. Co. ... 260
Allen, Edwin ..... 312
Allen, W. H., Son & Co., Ltd. ..... 92 & 105
Allen & Simmonds ..... 24 & 37
Andrews' Governor Patents, Ltd. ..... 19 & 42
Atlas Metal & Alloys Co., Ltd. ..... 207
Bailey, W. H. & Co., Ltd. ..... 237 & 244
Barker, John & Co., Ltd. ..... 165 & 172
Barlow, H. B. ..... 270
Bates & Peard Annealing Furnace Co. ... 273
Beanland, Perkin & Co. ..... 282
Becker, R. & Co. ..... 228 & 252
Beldam Packing and Rubber Co. ..... 27 & 34
Bergtheil & Young, Ltd. ..... 216
Brandon, E. C. & Co. ..... 187 & 223
Britannia Foundry Co. ..... 61 & 72
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British Coin Handling Machine Co., Ltd. ..... 297
British Gas Furnace & Tool Co., Ltd. .....
Budgett, H. M. ..... 62 & 71
Bullivant & Co. ..... 204 & 206
Burton, Griffiths & Co. ..... 124, 142 & 144
Butler, J. & Co. ..... 198 & 212
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Carborundum Co. ..... 156 & 182
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Chaplin, G. H. & Co. .....
Churchill, Chas. & Co., Ltd. ... 132, 140 & 146
Clarke, Chapman & Co., Ltd. ..... 91 & 106
Cochran & Co., Ltd. ..... 89A
Colchester Lathe Co. ..... 89 & 108
Coles Universal Buffer Coupler Co., Ltd. 296
Collet & Engelhard ..... 234 & 247
Combination Metallic Packing Co. ..... 131
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Cosmos Typewriter Co. ..... ... 153 & 185
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Cradock, Geo. & Co. ..... 168 & 169
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Drummond Bros., Ltd. ..... 123
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Dunston Engine Works Co. ..... 268
Empire Roller Bearings Co., Ltd. ... 229 & 251
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Facsimile Letter Printing Co., Ltd. ..... 157A
Fairbanks Co. ..... 143
Falcon Iron Works, Ltd. ..... 319 & 338
Fastnut, Ltd. ..... 63 & 70
Forced Lubrication Co., Ltd. ..... 202A
Foster Arc Lamp & Engineering Co., Ltd. ..... 20 & 41
Gibson, Arthur L. & Co. ..... 299A
Glacier, Anti-Friction Metal Co., Ltd. ... 90A
Glenfield & Kennedy, Ltd. ..... 232 & 249
Glover, M. & Co. ..... 49 & 84
Green, E. & Son, Ltd. ..... 162 & 175
Greenwood & Batley, Ltd. ..... 150
Hammond & Stow, Ltd. ..... 17 & 43
Hathorn & Co. ..... 271
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Hopkinson, J. & Co., Ltd. ..... 138 & 148
Hornsby, R. & Sons, Ltd. ..... 12
Howard Bros. ..... 64 & 69
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Hughon, M. A. & Co. ..... 191
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Johnson-Lundell Electric Traction Co., Ltd. ..... 20 & 41
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Kent, Geo. ..... 264
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Kirchner & Co. ..... 288 & 290
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Llewellin's Machine Co. ..... 239 & 242
Loewe, Ludw. & Co., Ltd. ..... 299 & 302
London Sheradizing Co., Ltd ..... 187 & 223
Lowca Engineering Co., Ltd. ..... 113 & 134
Lumsden Machine Co., Ltd. ..... 188
Lune Valley Engineering Co. ..... 270A
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Magnoid Co., Ltd. ..... 217
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Mayer & Schmidt ..... 240 & 241
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As before stated, the characteristic feature of the exhibition is the machine tools, of which there is a collection of unusual excellence, including numerous examples from America and Germany.

In the following preliminary account, brief mention will be made of the more important exhibits, reserving full illustrated descriptions of the models embodying new features until the next issue.

Messrs. Alfred Herbert, Ltd., Coventry, show a very complete collection of tools in actual operation. The stand itself is a workmanlike but light structure, composed of steel girders, the line shaft being placed centrally and driven by a 30 h.p. motor carried on top of the stand. The machines are arranged in two rows, down each side of the stand, and are driven from above by countershaft.

The exhibits comprise a combination turret lathe with patent chasing saddle, for dealing with heavy chucking work, and is shown in operation machining bevel gear blanks. Other lathes include No. 6 and No. 4 capstan types, the latter representing the smallest size for chuck work, and is shown in operation machining small commutator bushes. A No. 2 hexagon turret lathe is shown producing bolts from mild steel bar. Other tools are a No. 2 full automatic screw machine, a heavy vertical milling and profiling machine, a No. 1 vertical miller, and two horizontal milling machines with patent dial feed motion. A "Newall" universal grinding machine has a large number of valuable features, among which may be mentioned a variable speed drive to the work table and the ease with which the speed of the work can be changed. Another interesting machine is a worm wheel generator, which is shown in operation generating worm wheels by means of fly cutters, and is capable of generating worm wheels of very quick lead. A 9 in. centre heavy reduction lathe, a gear hobbing machine, and a 6 in. cold saw of particularly neat design complete this exhibit.

Messrs. Butler & Co., Halifax, exhibit a 48 in. vertical boring and turning machine, a 10 in. stroke slotting machine, a planer, high-speed drilling machine, and a portable drill.

Messrs. John Holroyd & Co., Ltd., Rochdale, show a No. 2A screw milling machine for cutting worms and all kinds of square and acme thread screws. The size shown is suitable for motor car builders, general engineers, machine tool makers, &c. A 36 in. "B" type universal gear hobbing machine cuts spur, worm and spiral gears up to 1 in. pitch from the solid by means of a hob. Only one hob is wanted for each pitch, and every wheel, no matter what number of teeth, is cut accurately to correct shape. Two hack sawing machines, in which the bar, being cut, is revolved slowly, whilst the saw reciprocates so that the saw-blade cuts round the bar, from which the cuttings fall away easily. The blade is always at work on a small area, ensuring very rapid cutting, whilst the blanks produced are as true as if parted off in a lathe. Also shown is a 24-in. worm wheel hobbing machine, which hobs worm wheels up to 1 in. pitch from the solid accurately and quickly. A 24-in. dia. circular milling machine for circular milling light pulleys, change wheels, &c., effecting a great saving compared with lathe turned work. An entirely new machine is the internal and external screw milling machine for milling external and internal threads on rings and screws. Screws are milled with an ordinary thread cutter or with a comb section cutter. In the latter case the cutter corresponds to the whole length of thread to be cut, and the operation is effected by one revolution of the work. A turret lathe, horizontal plain milling machine and a "Universal" cutter sharpening machine for sharpening all kinds of milling cutters completes this stand.

At the stand of Messrs. Charles Churchill & Co., Ltd., two examples of the turning lathes are shown, one being a typical example of modern practice, and the other an antique specimen showing a comparatively early stage of the revolutionary process. This latter machine eloquently suggests the mechanical limitations by which our predecessors were handicapped—and for which due allowance is not always made when judging of their achievements: from an archæological point of view, this will be of quite as much interest as the modern tool, which is a well designed high speed lathe by Ernault, meriting careful attention. The revolving spindle, equipped with a die to which the ends of rods, could be applied in succession is the primitive idea modified and developed till we have the screwing machine, of which an excellent example is on view, fitted with a self-opening die head of substantial and ingenious construction. Those interested in rapid, uniform, and economical screwing would do well to inspect this machine with

care. A more important modification of the lathe brings us to the turret machine, in which a bar passing through the hollow live spindle is operated on by a series of tools till the required part is completed and cut off, whereupon the bar is brought forward the necessary distance and the cycle of operations is repeated. The "Warner & Swasey" hexagon turret lathe, and the "N. & W." combination turret machine form good examples of semi-automatic repetition tools of this class.

Still more specialised and complex developments of the same general idea bring us to the fully automatic machines, in which cams assume the functions of the operator, and enable the machines to perform their allotted tasks without constant individual attention and manipulation on the part of the attendant. In the "Simplex" machines (of which two are shown at work) four bars are operated on simultaneously with a very largely increased output as the result. A two-spindle machine of the same make, which is specially adapted for the manufacture of nuts and similar pieces, is also exhibited. A "Potter & Johnston" automatic chucking and turning machine applies similar methods to the handling of castings and forgings, and has an ingenious arrangement by which both ends of the piece can be machined at the same time. In this way a second chucking is in many cases avoided, and greater accuracy, as well as increased speed, secured.

Plain and universal grinding machines, of latest design, can also be seen, as also a No. O "Biernatzki" gear generator, and a duplex gear shaper which works at a high speed and rapidly cuts the teeth to the required form The machine works to the cone lines of the gear and so produces a tooth which is exact in shape and proportions from end to end. The two sides of the gear are planed simultaneously, which, however, are both controlled by a single former. This ensures both sides of the tooth being precisely alike, reduces the cost of formers, as compared with machines employing two separate ones, and allows any desired form of tooth to be produced.

Among the other matters of interest on this stand may be mentioned the following: A semi-automatic screw slotting machine; an admirable little machine for quickly forming the heads on rivets by a noiseless spinning action; a useful wet emery tool grinder, with a gravity water supply of particularly good type and a highly efficient trueing device; Norton "Alundum" grinding wheels, and a selection of small tools and cutters of both carbon and high speed steels.

Drummond Bros., Ltd., Guildford, show a complete line of small lathes specially designed for motor repairing; a small hand lever bench shaping machine and a heavy 6 in. centre, 9 ft. gap bed lathe, the latter being an extremely powerful tool designed for use with high speed steels in general manufacturing work.

The Consolidated Pneumatic Tool Co., Ltd., Westminster, on one of the most conspicuous stands in the exhibition, show "Boyer and Keller" hammers for both stone and metal. There are also "Boyer," "Keller," "Little Giant" and "Whitelaw" drills for drilling in metal, tube expanding and cutting, reaming, tapping, &c. Another feature is a pneumatic grinder and polisher.

An air compressor and receiver is shown, together with all hose pipes, connections, accessories necessary for showing the several classes of machines under full working conditions. The plant is driven by an electric motor. A full complete assortment of electric drills with magnetic drill posts are also shown in operation.

Henry Pels & Co., 9, Portsmouth Street, Lincoln's Inn Fields, have an interesting collection of their well-known machines, which are built up of steel throughout. They include a "John's" joist shear double-ended notching machine, bar angle and tee and channel cropper, bevel cropper and splitting shears.

Messrs. Pfeil & Co., Clerkenwell, show two full automatic bevel gear planing machines, which generate the shape of the teeth by means of a roll cone and are operated without formers. Two semi-automatic machines are worthy of attention, as is also a self-developing spur gear cutter for generating gears by means of a hob. Other machines include a special lathe for tap making with automatic knock out; universal grinding machine; relieving lathe; vertical and planer type milling machines; "Auerbach" capstan and opticians' lathes, and high speed reduction lathes. In addition to the above are a variety of milling machines, sensitive drills, screw head slotters, cutter and twist drill and disc grinders.

Mr. H. M. Budgett, of Chelmsford, shows shop accessories in the shape of surface plates, cast-iron straight edges, tribar for truing up the gibs of machine tools, parallel strips and "Vee" blocks.

Messrs. Craig & Donald, Johnstone, show a new type of four-roller plate-flattening machine to work steel plates up to 5 ft. wide by ¾ in. thick, suitable for bridge works, shipyards, &c., &c. It is

claimed that this machine is easier manipulated, and does the work quicker than any other type of multiple rolls, besides being less costly, and occupying less floor space. The exhibit shows the machine working with electric motor drive; also an interesting working scale model of a four-roller type combined plate bending and plate straightening rolls. This machine is arranged with a swing cheek to enable plates that have been bent into complete circles being removed from off the top roller. Other models include a cam and lever type punching, shearing, and side-notching machine, as used in shipyards, and an eccentric type punching, shearing, and angle-iron cutting machine.

Messrs. Pollock & Macnab, Ltd., have a fine collection of lathes, drilling machines and a single geared crank shaper. Among the former class may be mentioned a combination turret lathe for chucking work up to 23 in. swing, and for bar work up to 4 in. diameter. Messrs. H. W. Ward & Co., Birmingham, have a noteworthy collection of lathes, the latest type being represented by a heavily built, well-designed 12 in. centre all-gear combination turret machine for all classes of chucking and bar work.

Several plain milling and grinding machines are also displayed.

Kendall & Gent, Ltd., Manchester, display some fine tools, consisting of a 2-in. spindle plano profile milling machine, with elevating cross slide and countershaft; a No. 3 size vertical milling and profiling machine; a No. 1 "Dixon's" patent radial drilling and tapping machine, with drilling spindle 2¼ in. dia. and separate tapping spindle for tapping holes up to 1¼ in. dia., after drilling without stopping or altering the speed of the machine. There is also an automatic screwing machine, "Brown & Dixon's" patent, and an improved cutter grinding machine, with two spindles, fitted also with twist drill grinding attachment.

Another Manchester firm of tool makers — Messrs. Cunliffe & Croom, Ltd., exhibit a patent planing machine with self-contained motor drive, a vertical planer-type milling machine; two swing vertical turning and boring mills and several plain milling and drilling machines. On a neighbouring stand Messrs. Greenwood & Batley, Leeds, show an 8-in. automatic bevel wheel shaping machine; a universal and copy grinder; an 8½-in. centre boring and reamering lathe and a straight milling machine.

Joshua Heap & Co., Ltd., Ashton-under-Lyne, have a fine display of screwing and tapping machines for tubes, bolts and nuts, and Messrs. Selig, Sonnenthal & Co., Queen Victoria Street, show amongst others, horizontal and vertical milling machines; new patent high-speed lathe; new type boring and surfacing lathe; patent oil-grooving machine, for endless spiral grooves; automatic hobbing machine; sensitive radial drilling machines; new universal grinding machine and new water tool grinders.

Sanderson Bros. & Newbould, Ltd., Sheffield, show a high-speed lathe by Messrs. John Stirk & Sons, a drilling machine by Tangyes, Ltd., and a cold sawing machine by Clifton & Waddell, to demonstrate the adaptability of "Saben" high speed steels for the various operations performed by the machines. In addition to the 10 in. lathe mentioned above, Messrs. Stirk & Sons exhibit tools on their own stand, consisting of a 30' in. boring and turning mill; an 8 in. gap lathe and an 8 in. special pattern high speed lathe, of which a full description will appear later.

Messrs. Ludwig Loewe & Co., Ltd., of Farringdon Road, have a representative collection of machine tools, many of which are in operation. The latter include a "Loewe" universal milling machine fitted with the "Loewe" patent automatic indexing apparatus. This new and invaluable attachment automatically operates the dividing head, and while effecting a great saving in labour, obviates all risk of wrong divisions being made. The large "Loewe" vertical milling machine, which is especially adapted for milling pieces of irregular outline, such as gear boxes, is shown machining the latter. The advantages of the circular milling machine over the lathe for a certain class of work is practically demonstrated. The "Defries" keyway cutting machine is unique, inasmuch as it automatically mills keyways to the desired depth and length in one cut. Another machine shown in operation is the "Tindel-Albrecht" crankshaft lathe. Special mention may be made of the 10 in. by 50 in. "Norton" cylindrical grinder, which is used to give practical demonstration of the modern tendency to rough turn in the lathes and then grind to size. The various "Fontaine" saw sharpeners and cutter grinders, which are entirely automatic in action and most efficient machines, are shown fulfilling their various purposes. Among other machine tools may be mentioned:—Spur gear cutting machine, turret lathe with chain-driven feed, pin and stud machine, drilling machine, "Colburn" vertical boring mill, several types of "Rumpf" screw-cutting lathes, &c. In

addition to the foregoing, there is a fine selection of "Loewe" small tools, standard and limit gauges, also a large variety of micrometers, calipers, spirit levels, speed indicators, and the English-made "Grip" keyless drill chuck. Further, a representative range of the well-known "D. W. M." ball bearings, including a new type which is provided with a one-piece bronze cage for the balls in order to meet the wishes of customers preferring a solid ball retainer. The "Conrad" Plummer blocks and hangers are specially designed to take these bearings, and are used for the line shaft on the exhibition stand.

Foreign firms exhibiting are Messrs. Collet & Englehart, who show a travelling electric drilling and tapping machine; Meyer & Schmidt, Offenbach, a varied selection of grinding machines; Gustav Wagner, Wurtemburg, cold sawing machines; and George Wuttig, of Dresden, who displays examples of a new automatic screw-making machine for cutting threads without reversing, the spindle and cutter running uninterruptedly in the same direction.

*Steam and Gas Engine Plant and Accessories.* The display in this direction is certainly disappointing. Nevertheless some well-known firms are represented, amongst whom must be mentioned Messrs. W. H. Allen & Co., Bedford, who show a three-crank, three-cylinder compound vertical enclosed high-speed engine, developing 300 b.h.p. at 450 revolutions per minute, with 100—200 lbs. steam pressure. The engine is fitted with valves of the piston type, and is so designed that it is impossible for oil to pass up into the cylinders from the crank chamber, or for water to find its way from the cylinders into the engine. Two other high-speed engines of the same character are shown, one of 220 b.h.p. and the other of 130 b.h.p. Other items on this stand are a three-throw "Allen-Edwards" air pump, two belt-driven centrifugal pumps and a low-lift turbine pump. Messrs. Reavell & Co., Ltd., Ipswich, show a high-speed, enclosed type double-acting engine, developing 14 b.h.p. at 600 revolutions per minute at 140 lbs. steam pressure. This engine is suitable for dynamos or fan driving. Air compressors, however, form the chief feature of this stand. They comprise a single ended, two-stage, water jacketed, quadruplex compressor, having a capacity of 260 cubic ft. free air per minute, when running at a speed of 275 revolutions per minute; one three-stage, single ended, high-pressure, jacketed, quadruplex air compressor, having a free air capacity of 70 cubic ft. per minute, when running at a speed of 325 revolutions per minute; one single ended, two-stage, water jacketed, quadruplex air compressor, having a free air capacity of 230 cubic ft. per minute, speed 315 revolutions per minute. The special feature about this machine is that the motor and compressor are directly coupled to each other, making a very compact plant, and so arranged that there are only two bearings to carry the whole of the rotating parts. It is the type of machine this firm offer for the supply of compressed air for pneumatic tools or for mining work. An interesting item is a special duplex, unjacketed air compressor, as used for central station cleaning. The plant is mounted on rubber-tyred wheels, and it is suitable for any working pressure up to 30 lbs. per sq. in.

E. S. Hindley & Sons, Bourton, Dorset, exhibit a vertical high-speed gas engine direct-coupled to continuous current dynamo, 15 k.w., 200 volts at 600 revs., combined with a suction gas producer plant; a vertical semi-enclosed high-speed steam engine, cylinder 7 in. diameter by 7 in. stroke, direct-coupled to continuous current dynamo, 17½ k.w., 200 volts, 450 revs.; a vertical enclosed high-speed steam engine, and developing 45 b.h.p. at 550 revs.; and a 3 b.h.p. horizontal medium-speed open type steam engine. These multi-cylinder gas engines have been recently introduced by the firm, and represent all the modern improvements in gas engine practice modified as far as is necessary in view of the high speed attained.

The National Gas Engine Co., Ashton-under-Lyne, show an "ME" type engine, together with a direct-coupled dynamo, and one of the firm's latest type suction producer gas plants. This installation is capable of serving 60 to 70 16 c.p. lamps, and it is very suitable for a country residence. Also mounted is a small petrol engine suitable for farmers' work or for such work where gas is not available.

Richard Hornsby & Sons, Ltd., Grantham, show a 17 b.h.p. gas engine and suction plant, the engine being direct-coupled to a Lancashire dynamo by flexible coupling. Crossley's exhibit consists of a high-speed gas engine working on gas from a suction plant, and driving a dynamo for lighting the stand. The engine develops 49 effective h.p. on town gas and 39 effective h.p. on suction gas.

A striking exhibit is that of the Pulsometer Engineering Co., Reading, who

exhibit the largest and smallest size pulsometer steam pumps. The former measures 126 in. and throws 150,000 gallons per hour; the latter is only 17 in. high and has a capacity of 750 gallons per hour.

McPhail & Simpson, Ltd., Wakefield, show a complete downtake superheater, tube plates, headers, superheater tubes and stop valves specially constructed for superheated steam.

W. H. Bailey & Co., Ltd., Salford, have a representative show of their specialties consisting of air-compressors, steam pumping engines for boiler feeding and general purposes, and boiler mountings and engine fittings of almost every type. Special interest attaches to the key-ring renewable valve seat, the "Thurston" recording oil tester, and to a patent hydraulic installation recorder specially made for the new hydraulic power station at Falcon's Wharf.

Messrs. Thwaites Bros., Ltd., Bradford, have a miscellaneous, but none the less interesting, exhibit, among which may be noted several improved type "Roots" blowers; an electrically-driven air compressor; the variable delivering 3-throw electrically-driven pump before mentioned; Bradford patent feed pumps and a Clayton fire extinguishing and disinfecting machine.

Boiler mountings, steam and water valves figure in profusion on the stand of J. Hopkinson & Co., Ltd., Huddersfield, notable among which are the "Hopkinson-Ferranti" patent steam stop valve, silent automatic exhaust valve, automatic feed water regulator, and a new flue tube for the Lancashire boilers.

Another of the few steam engines is to be found on the stand of Samuelson & Co., Ltd., Banbury, who also display a selection of "Roots'" blowers and pumps, and a portable smith's forge.

E. Green & Son, Ltd., Wakefield, display models of their well-known fuel economisers with the scraper gear in operation, a high-speed engine for driving economised gearing, mechanical stokers or conveyors; sample castings of economiser tubes and photographs of economiser installations.

Messrs. Dobbie, McInnes, Ltd., show a number of indicators, amongst which may be mentioned one specially suitable for winding engines and another a double diagram instrument recording from both ends of the cylinder and giving time and revolution diagrams. Messrs. Sanders, Rehders & Co., exhibit a representative collection of the now generally known "Sarco" fuel economy specialties.

Messrs. Clarke, Chapman & Co., Ltd., have a fine representative display of their leading specialties. There are motor-driven shipyard and baggage winches, a steam winch of the cyclops type, an electrically-driven 3-throw pump, electric generating plants, electric drills, a 24 in. projector, the steam drum of a "Clarke-Chapman" water-tube boiler (Woodeson patent), pair of direct-acting slow speed feed pumps fitted with Woodeson's patent steam-thrown valve gear, steam windlass, and a steam warping capstan.

The Crosby Steam Gage & Valve Co. have a representative display of indicators, safety valves, pressure gauges, and other steam accessories.

One of the novelties of the show is a method of belt-lacing introduced by J. B. Stone & Co., who are selling this in conjunction with the well-known "Clipper" and "Peerless" appliances. As we shall illustrate this in our next issue, it will suffice to state here that it is a flexible lacing that will go into any kind of belting, nothing being needed but a hammer to effect the splice. Fully 80 per cent. of the belts at the Exhibition have been laced by this method. The firm are also exhibiting a chain saw mortising machine, "Fox" pattern trimmers, dovetailing machine, and a number of other machinery and tools suitable for pattern makers and joiners.

Woodworking specialties figure also on the stands of Messrs. Sagar & Co., Halifax; Kirchner & Co., Beanland; Perkin & Co., and M. Glover & Co., the latter staging their patent machinery for sawing, splitting, screening and bundling firewood.

Packings, friction-reducing metals and appliances are well to the fore at the stands of Willans & Robinson, Ltd., who show phospher bronze and white metal bearings; the United States Metallic Packing Co., Bradford; Jas. Walker & Co.; the Glacier Anti-Friction Metal Co., Ltd.; the Atlas Metals and Alloys Co.; the Hoyt Metal Co.; the Dixon Crucible Co.; the Dexine Patent Packing and Rubber Co., whose special composition takes the place of ordinary india-rubber and leather goods, as used for pump buckets, hat and cup rings, &c. The Forced Lubrication Co., Ltd., Manchester, show bearings and bushings fitted with their patent system of lubrication. Roller bearings are represented by the Hyatt Roller Bearings Co., 47, Victoria Street, S.W., and the Empire Rolling Bearings Co., at the stand of the former being a curiosity in the shape of a huge model of the "Hyatt" flexible roller, suspended overhead and evolved by means of

a small electric motor. Castings of various kinds figure on the stands of Aerators, Ltd., who show alloy die finished castings; Thos. Butlin & Co., Ltd., Wellingborough, cupola castings, particularly pipes; and at that of Norman & Young, Ltd., who display die finished castings in aluminium and various hard alloys. The Britannia Foundry Co., Coventry, in addition to their patent moulding machine, exhibit samples of castings in iron, aluminium, and gun metal as produced by the machine.

Grinding specialties are represented by the Carborundum Co. and Markt & Co., with an assortment of grinding wheels and sharpening stones.

Electrical engineering is not prominently in evidence. The Phœnix Dynamo Co., Ltd., Bradford, limit their exhibits to electric drills and grinders, although a number of the firm's motors are employed throughout the exhibition; the Foster Arc Lamp & Engineering Co., Ltd., to arc lamps of the ordinary and flame type, while the Johnson-Lundell Electric Traction Co., Ltd., Southall, show a range of their patent laminated type of constant and adjustable speed electric motors and a 15-k.w. motor generator set.

Flame arc lamps by the Reason Manufacturing Co., Brighton, figure conspicuously on the stand of THE ENGINEERING REVIEW, the lighting of which forms one of the features of the show. The electric aspect of the exhibition will be dealt with by Mr. Andrew Stewart, A.M.I.E.E., in a special contribution to the next (Olympia) number.

Messrs. Bullivant & Co., Ltd., have a conspicuous and varied exhibit of steel wire ropes and all appliances in connection therewith, another prominent stand being that of the Lowca Engineering Co., Ltd., who show a series of machines representing a new system of conveying and screening coal and other materials. The "Fastnut" washer is, of course, in evidence; a great deal of attention is attracted by "Castolin"—a new brazing material for cast iron, of which we shall have more to say in the next issue. Messrs. Summerscales & Co., Keighley, have the field to themselves in laundry machinery with two ironers and one washer, also to be noticed in detail later.

In concluding this preliminary account, mention may be made of the interesting features to be found at the stands of the Non-explosive Ga Co., Ltd., and the Bates and Peard annealing furnace.

# Machine for Weighing the Forces on a Cutting Tool.*

THE object of the machine is to measure the three component forces (at right angles to each other), which result in the formation and separation of a chip of metal in a lathe. The forces are designated as follows:—

| | |
|---|---|
| The *vertical* force is called . | $X$ |
| The *horizontal* force (at right angles to the lathe axis) . | $Y$ |
| The *horizontal* force (parallel to lathe axis) . . . . | $Z$ |

These forces are balanced by weights $P$, $Q$, and $R$, applied at a greater distance from the fulcrum.

Fig. 1 is a sketch of the essential features. The tool, secured in a holder, is carried by a diaphragm of steel; for very small displacements only the device forms a universal frictionless pivot. Exact location of the long arm is effected by means of hardened steel contacts, one of each pair being insulated from the general body. A telephone receiver in circuit with each pair of contacts enables the operator to make an observation. The force $Y$ is balanced in the same manner through a bell-crank lever, not shown.

An experiment is made as follows:—

The lathe is run at a given speed, depth of cut, and traverse arranged for, and the tool fed up to the work. As soon as possible the forces are balanced and brought to a working mean—that is, contact is made at regular intervals at all the stops. Each force is then separately balanced for its *maximum* and *minimum* values. Friction on the stops is thus avoided.

* Paper read before the British Association.

Before the force itself can be measured by a single experiment, it is necessary to know the *centre of pressure*—that is, the point at which all the small forces in action may be assumed to act. This may be situated anywhere within the body of the shaving; and while for very small depths of cut its position may practically coincide with the centre of depth, with deep cuts and a short length of tool the divergence may be noticeable.

In any case it is an advantage to have this information. It may be found together with the real value of the forces in the following way:—

Referring again to Fig. 1,

Let $x$ be the distance from the fulcrum to the *centre of pressure*.

Let $p$ be the distance from the fulcrum to weight $P$.

Then, by taking moments about the fulcrum, we get

$$X\,x = P\,p \quad . \quad . \quad (1)$$

If we now change the length of tool and balance under the same conditions as to cut, speed, &c., we get

$$X\,(x + \delta\,x) = (P + \delta\,P)\,p\,. \quad (2)$$

Subtracting (1) from (2)

$$X\,\delta\,x = \delta\,P\,p \text{ or } X = \frac{\delta\,P\,p}{\delta\,x}.$$

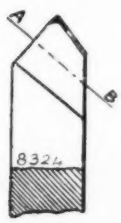
*Note.*—This is the real value of the force $X$, and by inserting in equation (1) we get $x$ the distance required.

Direct method:

$$\frac{X\,x}{X\,(x + \delta\,x)} = \frac{P\,p}{(P + \delta\,P)\,p} \therefore x = \frac{P\,\delta\,x}{\delta\,P}.$$

In working out the final values of the forces, calibration curves are used. The curves show the relation between the experimental forces, and the actual moment on the opposite side of the system.

In no experiment I have made are the forces constant in value, and the exact nature of the fluctuation is not accurately known. Dr. Nicholson, of Manchester, has shown this fluctuation by measuring the forces at small intervals with a very slow cutting speed. The author has also published some photographs illustrating the formation of a chip. The capabilities of the machine, however, are such that when the *maximum* and *minimum* are well defined, they can be measured with accuracy.




The tools used were of simple shape, with diamond points slightly flattened. In plan the cutting edge makes an angle of 45 deg. with the axis of the work.

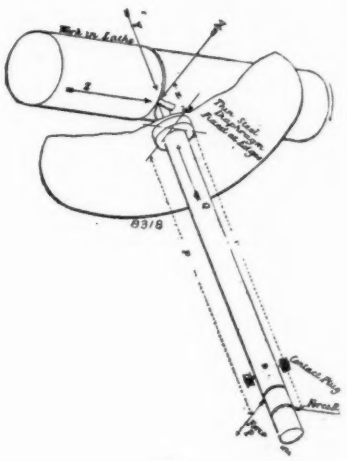



FIG. 1.

The cutting angle is measured on the plane $AB$, and was accurately formed on a machine grinder.

Clearance in all cases is 7·5 deg.

Material operated on is as follows:—

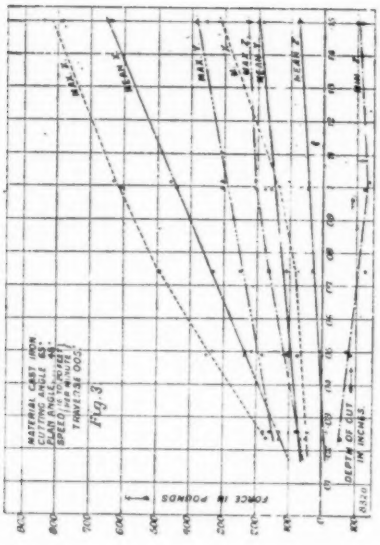
| | | | |
|---|---|---|---|
| Cast iron, average crushing resistance | ... | ... | 25 tons per sq. in. |
| Mild steel, average crushing resistance | ... | ... | 43 " " |
| Mild steel, tenacity—nominal | | | 34·5 " " |
| " " real | ... | | 58·5 " " |
| With an elongation on 2 in. of | | | 32 per cent. |
| Reduction of area | ... | ... | 50·8 " |
| Elastic limit | ... | ... | 17·85 tons. |

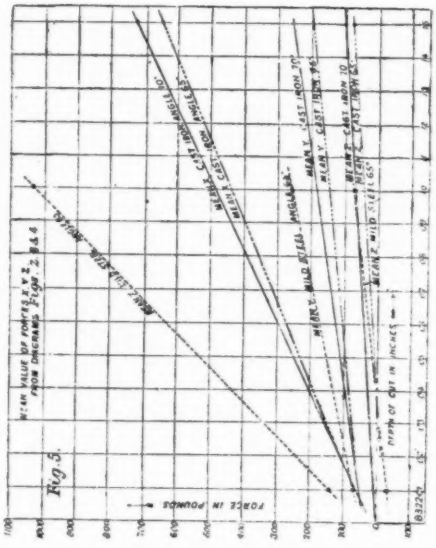
COMPOSITION.

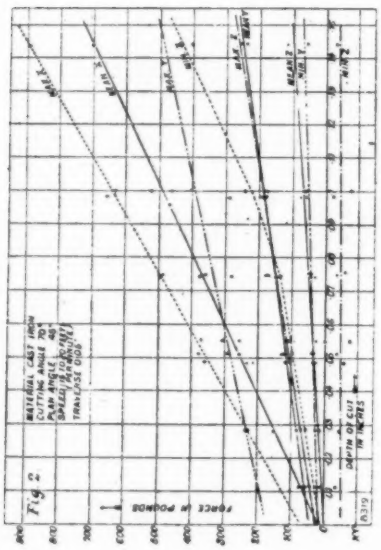
| | Per cent. |
|---|---|
| *Cast Iron:* | |
| Combined carbon ... ... ... ... | 0·315 |
| Graphite ... ... ... ... ... | 3·26 |
| Silicon ... ... ... ... ... | 2·193 |
| Sulphur ... ... ... ... ... | 0·039 |
| Phosphorus ... ... ... ... ... | 0·991 |
| Manganese ... ... ... ... ... | 0·721 |
| *Mild Steel (Acid Bessemer):* | |
| Carbon ... ... ... ... ... ... | 0·22 |
| Manganese ... ... ... ... ... | 0·936 |
| Silicon ... ... ... ... ... ... | 0·047 |

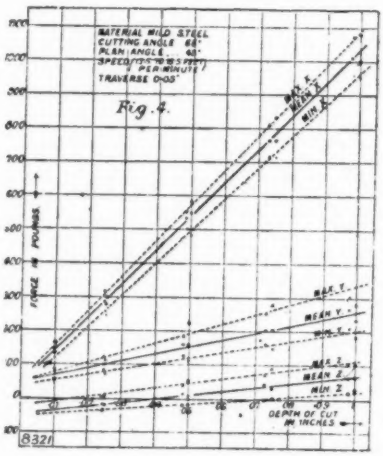
*Results.*—Tables of data showing three sets of experiments, together with curves illustrating same, are appended.

Straight lines have been drawn on the diagrams as indicating the probable relations between the forces and the depths of cut. In the experiments on mild steel these are very near the truth, and represent many separate experiments performed at different times. With cast iron the results are not so good, and represent one of its chief characteristics—that is, heterogeneous and open structure.


MATERIAL CAST IRON
CUTTING ANGLE 63°
PLAN ANGLE 45°
SPEED (100 FEET PER MINUTE)
TRAVERSE 0·005"
Fig. 3
FORCE IN POUNDS
DEPTH OF CUT IN INCHES
8320


MEAN VALUE OF FORCES X Y Z FROM DIAGRAMS Fig. 2 P & S 6
Fig. 5.
FORCE IN POUNDS
DEPTH OF CUT IN INCHES
8320


MATERIAL CAST IRON
CUTTING ANGLE 70°
PLAN ANGLE 45°
SPEED (100 FEET PER MINUTE)
TRAVERSE 0·005"
Fig. 2
FORCE IN POUNDS
DEPTH OF CUT IN INCHES
8319


MATERIAL MILD STEEL
CUTTING ANGLE 68°
PLAN ANGLE 45°
SPEED (100 FEET PER MINUTE)
TRAVERSE 0·005"
Fig. 4.
FORCE IN POUNDS
DEPTH OF CUT IN INCHES
8321

| No. | Speed. | | Diameter. | | Depth of cut. | Traverse per revolution. | X. | Y. | Z. |
|---|---|---|---|---|---|---|---|---|---|
| | Revolutions | Ft. per min. | Before. | After. | | | | | |
| | | | in. | in. | in. | in. | | | |
| 135 | — | — | 4·794 | — | — | — | 361 | 215 | 114* |
| | 16·25 | 19·9 | — | 4·697 | — | 0·05 | 235 | 104 | 35† |
| | — | — | — | — | 0·0485 | — | 93 | 28 | − 55‡ |
| | — | — | 4·697 | — | — | — | 659 | 292 | 193 |
| 136 | 16 | 19·9 | — | 4·501 | — | 0·05 | 481 | 182 | 72 |
| | — | — | — | — | 0·098 | — | 194 | 58 | − 19 |
| | — | — | 4·501 | — | — | — | 495 | 284 | 143 |
| 137 | 16 | 18·5 | — | 4·353 | — | 0·05 | 378 | 150 | 42 |
| | — | — | — | — | 0·074 | — | 135 | 33 | − 36 |
| | — | — | 4·353 | — | — | — | 227 | 235 | 70 |
| 138 | 16·27 | 18·4 | — | 4·297 | — | 0·05 | 149 | 80 | 13 |
| | — | — | — | — | 0·028 | — | 51 | 25 | − 50 |
| | — | — | 4·297 | — | — | — | 130 | 54 | 42 |
| 139 | 16·27 | 18·25 | — | 4·275 | — | 0·05 | 75 | 56 | 10 |
| | — | — | — | — | 0·011 | — | 25 | — | 36 |
| | — | — | 4·275 | — | — | — | 898 | 493 | 257 |
| 140 | 16 | 17·3 | — | 3·987 | — | 0·05 | 705 | 243 | 119 |
| | — | — | — | — | 0·144 | — | 434 | 58 | − 30 |
| | — | — | 3·987 | — | — | — | 370 | 305 | 118 |
| 141 | 16 | 16·5 | — | 3·877 | — | 0·05 | 257 | 103 | 25 |
| | — | — | — | — | 0·055 | — | 93 | — | − 65 |
| | — | — | 3·877 | — | — | — | 379 | 292 | 120 |
| 142 | 16·27 | 16·3 | — | 3·775 | — | 0·05 | 256 | 130 | 31 |
| | — | — | — | — | 0·051 | — | 97 | 32 | − 36 |
| | — | — | 3·775 | — | — | — | 479 | 450 | 171 |
| 143 | 16·13 | 15·6 | — | 3·626 | — | 0·05 | 369 | 182 | 51 |
| | — | — | — | — | 0·0745 | — | 134 | 42 | − 55 |
| | — | — | 3·626 | — | — | — | 636 | 529 | 181 |
| 144 | 16·13 | 14·9 | — | 3·426 | — | 0·05 | 464 | 243 | 68 |
| | — | — | — | — | 0·1 | — | 244 | 58 | − 70§ |
| | — | — | 4·774 | — | — | — | 170 | 242 ? | 64* |
| 145 | 16·55 | 20 | — | 4·727 | — | 0·05 | 128 | 53 | − 7 |
| | — | — | — | — | 0·0235 | — | 59 | — | − 55‡ |
| | — | — | 4·727 | — | — | — | 351 | 182 | 118 |
| 146 | 16·4 | 20 | — | 4·629 | — | 0·05 | 234 | 73 | 9 |
| | — | — | — | — | 0·049 | — | 76 | — | − 88 |
| | — | — | 4·629 | — | — | — | 497 | 242 | 165 |
| 147 | 16·4 | 19·6 | — | 4·480 | — | 0·05 | 331 | 112 | 28 |
| | — | — | — | — | 0·0745 | — | 76 | — | − 128 |
| | — | — | 4·48 | — | — | — | 631 | 305 | 202 |
| 148 | 14·65 | 16·8 | — | 4·277 | — | 0·05 | 455 | 143 | 42 |
| | — | — | — | — | 0·1015 | — | 106 | — | − 140 |
| | — | — | 4·277 | — | — | — | 840 | 354 | 232 |
| 149 | 16·15 | 17·5 | — | 3·977 | — | 0·05 | 647 | 196 | 77 |
| | — | — | — | — | 0·150 | — | 315 | — | − 103 |
| | — | — | 4·488 | — | — | — | 610 | 305 | 203 |
| 150 | 16·27 | 18·7 | — | 4·289 | — | 0·05 | 441 | 150 | 47 |
| | — | — | — | — | 0·0995 | — | 172 | — | − 124 |
| | — | — | 4·289 | — | — | — | 784 | 382 | 225 |
| 151 | 16·27 | 17·6 | — | 3·989 | — | 0·05 | 638 | 181 | 78 |
| | — | — | — | — | 0·150 | — | 305 | — | − 135 |
| | — | — | 3·989 | — | — | — | 332 | 214 | 107 |
| 152 | 16·55 | 17 | — | 3·889 | — | 0·05 | 237 | 102 | 6 |
| | — | — | — | — | 0·05 | — | 67 | — | − 77 |
| | — | — | 5·889 | — | — | — | 179 | 158 | 75 |
| 153 | 15·6 | 15·7 | — | 3·838 | — | 0·05 | 129 | 70 | − 12 |
| | — | — | — | — | ·0255 | — | 44 | — | − 107‖§ |
| | — | — | 4·295 | — | — | — | 319 | 123 | 69¶ |
| 154 | 16·55 | 18·5 | — | 4·2455 | — | 0·05 | 288 | 102 | − 16 |
| | — | — | — | — | 0·0247 | — | 260 | 82 | − 32‡ |
| | — | — | 4·2455 | — | — | — | 557 | 157 | 44 |
| 155 | 16·55 | 18·1 | — | 4·148 | — | 0·05 | 532 | 162 | 19 |
| | — | — | — | — | 0·0487 | — | 501 | 127 | − 16 |
| | — | — | 4·148 | — | — | — | 813 | 265 | 75 |
| 156 | 16 | 17·5 | — | 4·002 | — | 0·05 | 766 | 205 | 44 |
| | — | — | — | — | 0·073 | — | 716 | 162 | 6 |
| | — | — | 4·002 | — | — | — | 1080 | 283 | 106 |
| 157 | 13 | 13·3 | — | 3·802 | — | 0·05 | 1032 | 235 | 68 |
| | — | — | — | — | 0·1 | — | 953 | 187 | 24 |
| | — | — | 3·802 | — | — | — | 303 | 114 | 10 |
| 158 | 16·55 | 15·9 | — | 3·752 | — | 0·05 | 282 | 102 | 10 |
| | — | — | — | — | 0·025 | — | 247 | 75 | − 15 |
| | — | — | 3·752 | — | — | — | 582 | 227 | 53 |
| 159 | 16·55 | 15·65 | — | 3·652 | — | 0·05 | 545 | 162 | 10 |
| | — | — | — | — | 0·05 | — | 488 | 116 | − 15 |
| | — | — | 3·652 | — | — | — | 833 | 283 | 91 |
| 160 | 16·3 | 15·3 | — | 3·502 | — | 0·05 | 765 | 205 | 35 |
| | — | — | — | — | 0·075 | — | 716 | 150 | 3 |
| | — | — | 3·502 | — | — | — | 1072 | 305 | 108 |
| 161 | 16·3 | 14·5 | — | 3·806 | — | 0·05 | 1015 | 267 | 65 |
| | — | — | — | — | 0·098 | — | 956 | 213 | 22 |
| | — | — | 4 | — | — | — | 154 | 92 ‖ | 1 ‖ |
| 163 | 16 | 16·7 | — | 3·98 | — | 0·05 | 140 | 54 ‖ ? | — ‖ ? |
| | — | — | — | — | 0·01 | — | 124 | 55 † | − 2 † § |

* Material, cast iron. † Cutting angle, 70 deg. ‖ Cutting angle, 65 deg ‡ Tool, high-speed Mushet. ¶ Material, mild steel. § Tool in good order.

# NEW MACHINERY AND APPLIANCES.

**The Editor cordially invites early particulars of New Machinery, Improvements, Novelties, &c., for inclusion under this section.**

## A New Departure in Rock Drilling—The "Anderson" Detachable Bit for Power Drills.

The haulage of drill steel from the underground workings of a mine to the blacksmith's shop on surface, for re-sharpening necessitates a serious delay in the productive work of the shaft, the upkeep of a drill sharpening shop and the employment of skilled and other labour.

By the use of the "Anderson" detachable bit, which when blunted is replaced by a new one, the above is obviated, as one miner can carry fifty bits without inconvenience. The average weight of the bits is 6¾ ozs., and each bit has a hole through the centre, which allows it to be strung and carried over the shoulder. The permanent shanks (Fig. 3) to which the bits are fixed remain with the drilling machine (Fig. 2). Fig. 3 shows the method of securing the detachable bit to the shank.

A tie-rod with a triangular head passes through the centre of the bit and shank, and is secured by a nut at the rear end. Any lateral movement of the bit on the shank is prevented by the cylindrical projection in the base of the bit. The blow is carried on the flat surface around both ends of the shank.

A right or left-hand thread is employed according to the direction of rotation given by the drilling machine, so that the detachable bit always tends to tighten itself, though not to such an extent that it becomes difficult to remove the nut. To facilitate the tightening or loosening of the nut, there is a tommy hole near the rear end of the shank. This hole is also useful in turning the drill when coupled to the machine.

| | Approximate Length of each Drill. | Diameter of Bit. | Diameter of Bar on which the Bit is Forged. | Diameter of Bar where attached to the Chuck. |
|---|---|---|---|---|
| | ft. in. | in. | in. | in. |
| Starting Drill | 2 0 | 2¾ | 1½ | 1¼ |
| 2nd ,, | 3 6 | 2¼ | 1⅜ | 1¼ |
| 3rd ,, | 5 0 | 1⅞ | 1¼ | 1¼ |
| Finishing ,, | 6 6 | 1½ | 1⅛ | 1¼ |

9336

FIG. 1.

The method of attachment does not materially increase the size of the drill shank near the cutting bit, and allows ample clearance for the cuttings to escape. Should the detachable bit become irrecoverably jammed in the bore hole the shank can be removed.

The present solid drills are made from rolled or hammered steel bars. The usual proportions for a 6 ft. hole in hard rock are shown in above table.

FIG. 2.

With the "Anderson" detachable bit the proportions are:—

| | Permanent Length of each Shank. | Diameter of Detachable Bit. | Smallest Diameter of Permanent Shank. | Diameter of Permanent Shank where attached to the Chuck. |
|---|---|---|---|---|
| | ft. in. | in. | in. | in. |
| Starting Drill | 2 0 | $2\frac{1}{4}$ | $1\frac{1}{2}$ | $1\frac{5}{8}$ |
| 2nd ,, | 3 6 | $2\frac{1}{16}$ | $1\frac{5}{8}$ | $1\frac{3}{4}$ |
| 3rd ,, | 5 0 | $1\frac{7}{8}$ | $1\frac{1}{4}$ | $1\frac{3}{4}$ |
| Finishing ,, | 6 6 | $1\frac{1}{16}$ | $1\frac{1}{16}$ | $1\frac{1}{4}$ |

Fig. 4 shows the solid drill as compared with the "Anderson" detachable bit. The permanent shanks of the latter are $1\frac{3}{4}$ in. diameter where attached to the chuck and taper down towards the detachable bit to allow for sufficient clearance; they are also spring tempered, thus the greatest possible strength of shank is secured, whereas the present drills are only $1\frac{1}{8}$ in. diameter where attached to the chuck, and are left soft.

In starting a hole at a wide angle to the face of the rock, it is mostly a question of rigidity of the coupling between the drill shank and the piston rod, but the hole is bound to start slightly out of line however rigid the coupling may be owing to the spring of the parts. If, however, after drilling a few inches the nut that clamps the drilling machine in position be loosened, the piston rod and drill shank should have enough rigidity to pull the drilling machine into line with the axis of the hole while drilling. Again, when the drilling machine is near the end of its travel forward, it projects so far out of the guides that support it and keep it in line, that the position of the coupling between the shank and piston rod is under the same stress as the centre of a beam supported at both ends. From this it is evident that the greater the rigidity of this coupling the less the hole will tend to deflect upwards.

Owing to daily resharpening the solid drills become shortened, and as drills are worked in sets much time is lost in finding the necessary lengths and diameters to drill a hole. A serious loss of drill steel is incurred by having to discard all drills after a reduction in length of a few inches, as the finishing drill is of too small a diameter to be made into a starting drill (see table of sizes).

The permanent shanks for the "Anderson" bit are of standard lengths, and are so designed that any diameter of bit can be secured to any length of shank, the cylindrical projection in the base of all detachable bits being the same size (Fig. 5). As the drill advances in the bore hole, frictional wear takes place on the end faces of the chisel edges. These end faces form the guiding surfaces of the drill. The forged guiding faces on the solid drills (Fig. 4) are flat, although they have to act in a round

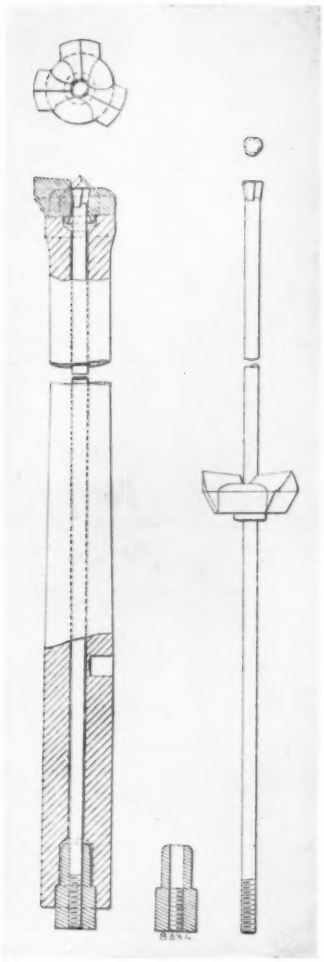


FIG. 3.

hole and the different guiding faces are not always forged the same distance from the centre. Again, as a rule, they are far too large and do not wear evenly, eventually causing the drill to jam in the hole and a sledge hammer is customarily used to loosen it. The "Anderson" bit can stand the same rough handling, but the bit has three guiding faces of small size and parallel with the axis of the hole (Fig. 6). They also form segments of the same circle (Fig. 5) and wear so evenly that the drill, it

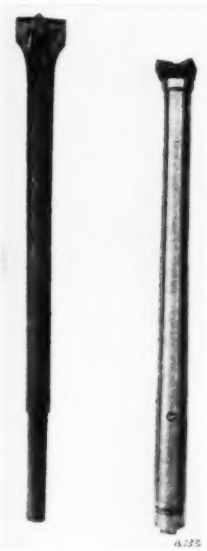


FIG. 4.

is claimed, is always free in the hole.

A reduction has to be made in the diameter of each succeeding bit to allow for the frictional wear, and with the solid drills an extra allowance must be made to cover the inaccurate forging. The "Anderson" bits are accurate and work with minimum frictional wear, and, we are informed, it is owing to this that the hole can be started $\frac{1}{2}$ in. less and finish $\frac{3}{16}$ in. larger than with the present solid drills.

The styles of cutting bits in present use are determined by some easily forged pattern such as a single chisel edge, cruciform or X shape. The method of manufacture of the "Anderson" bit does not limit the design.

The rate of drilling is not affected by the number of cutting wings on the bit, a chisel edge excavating in one blow approximately the same as a five-winged bit. With the latter, however the shock to the shank is greatly increased and the five cutting wings become very nearly as blunt in doing the same work. It is probably not generally known that a single chisel edge, when not working satisfactorily, makes a three-sided hole; a symmetrical three-edged bit a square hole; a cruciform bit a five-sided hole; and a symmetrical five-edged bit a six-sided hole.

The bit under notice has three cutting edges (which give stable equilibrium and transmit a direct blow down the shank) arranged to form angles of 90 degs, 120 degs. and 150 degs. This unequal spacing counteracts any tendency to groove the hole, and invariably forms a round one. The three edges do not run radially to the centre, but are made to vary so as not to strike in the same lines as each other. The irregular spacing also aids in starting a hole at an angle to the face of the rock (Fig. 6), because the blow does not continually fall in the same spot, the range of blow covering 150 degs., one blow aiding the other over this extended area by striking in a separate place and thus breaking ground.

The extremities of the cutting edges are

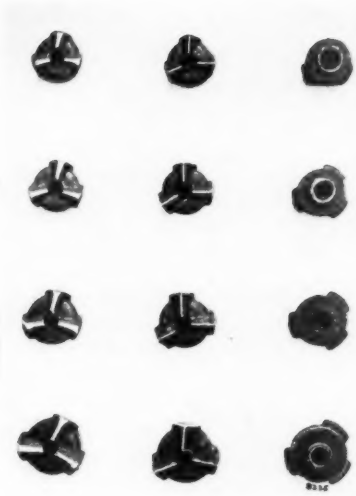


FIG. 5.

FIG. 6.

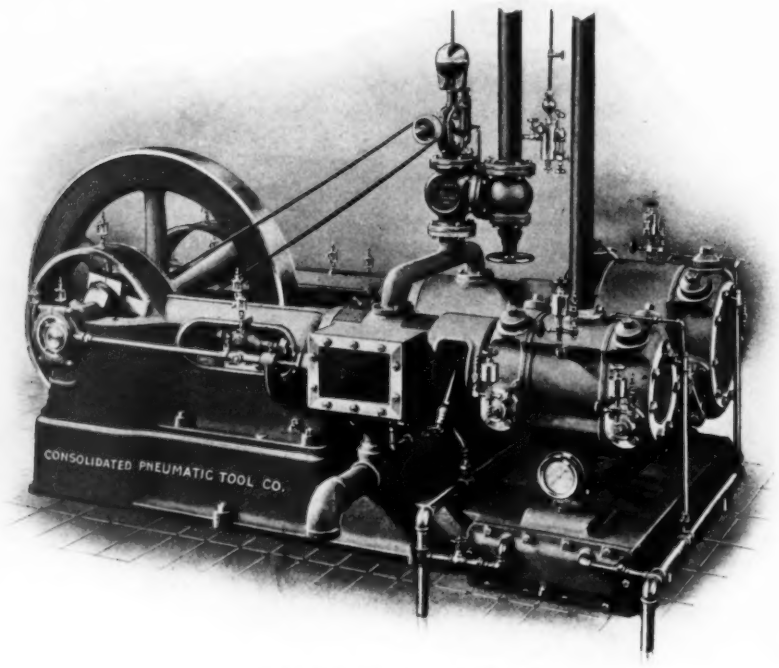
made ½ in. in advance of the centre, as in this position they dig out the circumference with less damage to themselves. When the extremities are slightly behind the centre, as is the case in the forged drill (Fig. 4), the digging effect is lost and the tendency is to rub out the circumference of the hole. The cuttings can escape more freely out of the bore hole when the circumference is in advance as the cuttings collect around the edge of the hole instead of in the centre. A speciality has been made of the hardening and tempering process, so as to produce a uniform result; the cutting edges being very hard, whilst the body of the bit is left soft, especially that part which bears against the hardened end of the shank. In this way the shank end is preserved. The bit can be adapted to any style of "U" bolt chuck at present on the market, by removing the bushing.

In Mount Sorrell and Aberdeen granite the average time taken over ten holes, 5 ft. deep, starting at angles of 30 degs. to the face of the rock, 2¼ in. diameter finishing 1-$\frac{1}{16}$ in. diameter, 70 lb. air pressure, including changing of drills, twenty minutes. These holes were started at full speed. The makers of this bit are Messrs. Thos. Firth & Sons, Sheffield.

## The New "Franklin" Air Compressor.

With the increasing use of pneumatic tools and appliances the most efficient means of producing compressed air becomes a matter of importance. Those employing this medium as a motive power will therefore be interested in the accompanying description and illustration of an improved type of compressor that is now being manufactured by the Consolidated Pneumatic Tool Company of Fraserburgh. The "Franklin" machine, as it is called, is the outcome of a lengthy series of investigations, and follows original lines on points vital to maximum efficiency.

Various types are made, that shown herewith being of a class especially suited to the requirements of industrial works, mines, quarries, &c. It is of duplex pattern, with simple or cross-compound steam cylinders and simple or two-stage air compressing cylinders, according to working conditions. A variety of combinations is obtainable for varying pressure conditions, and machines are also built for motor or water-wheel drive, either direct or by belt, gear or chain. These compressors are built in sizes ranging in capacity from 30 to 2,000 cub. ft.




THE NEW "FRANKLIN" AIR COMPRESSOR.

of free air per minute displacement for 10 to 125 lbs. per sq. in. working air pressure and suited to all compressed air uses.

The following are some of the more salient constructive features. The frames are heavy box-shape castings, strongly ribbed, with a large factor of safety to withstand strains when working at maximum load. The bottom surface bearing upon the foundation throughout its entire length insures stiffness, not only at the main bearing, but also along the guides and at the connection with the cylinder, and at the same time affords an even distribution of the stresses on the foundation and also of the internal stresses which the bed itself must sustain. The cross-head guides are bored, and provision is made for catching and draining drip from bearings and stuffing boxes. Being entirely self-contained, expensive foundations are avoided and expert erection services unnecessary. The cylinders are made from a mixture of special iron and selected scrap, and are of sufficient strength and thickness to withstand the pressure for which they are designed, after reboring. The steam cylinders have their exterior walls covered with asbestos or mineral wool, and are neatly lagged with planished iron. The air cylinders and cylinder heads are completely water jacketed, providing a thorough circulation of water with equal cooling at all points. The pistons are of the solid type, with cast iron spring rings. The shaft is of centre crank type of ample diameter, made of the best open hearth steel, with exceptionally heavy crank arms. The box cross-head is provided with taper shoes, turned to fit the cylinder guide. These shoes have a screw adjustment affording a ready means of taking up the slight wear and of securing proper alignment. Oil guards at each end of the lower slide on the bed give continuous lubrication to the lower shoe, while a sight-feed oil cup on top of the bed provides the necessary oil for the upper shoe.

The single type has two balance wheels, one on each side, to insure smooth operation. Duplex and cross-compound compressors have heavy fly-wheels made in

two sections, securely bolted together at the hub and at the rim.

Steam-driven compressors are provided with a pressure regulating governor to automatically control the operation of the compressor in accordance with the demand for air, working in connection with a speed governor, which regulates the speed of the compressor. The single-steam and belt-driven compressors also have an unloading device to relieve the compressor of all load when the desired air pressure is obtained, and automatically cause it to resume delivery when the receiver pressure becomes reduced. Smaller steam-driven compressors have plain D slide valves. Steam cylinders of 12 in. diameter or larger are provided with "Meyer" cut-off valves, the main valve being balanced.

A graduated scale indicates the point of cut-off, which may be adjusted from $\frac{1}{4}$ to $\frac{7}{8}$ of the stroke while the compressor is running.

The air inlet valves of the poppet type are made from high grade steel, having removable seats and guides, easily removed or repaired, and thoroughly guarded from entering the cylinder in case of breakage. They are placed radially in cylinder, rendering them accessible and insuring accurate seating.

Too much importance cannot be attached to the feature of accessibility, for the valves sustain the severest service of air compression and the heat incident thereto.

The valve stem and head are forged in one piece, entirely avoiding the use of flange nuts, jam nuts, split pins, or other contrivances intended to serve as a head for the stem, requiring constant supervision with continual liability to work loose. The valve seat is a part entirely separate from the cylinder proper and may be removed, replaced or renewed whenever occasion requires. In most forms of air compressors employing poppet valves the valve seat forms an integral part of the cylinder or cylinder head, affording no opportunity for renewal except by replacing the entire cylinder or head, whereas in the "Franklin" construction the valve and seat form a complete piece of mechanism which may be examined, reground and adjusted separate from the compressor. The valves and seats are placed in position after the heads are attached to the cylinder, and are held securely by large screw plugs. As the heads need not be removed, it is but a moment's work to take out the valve. The valve springs are of steel, light enough to minimise resistance in opening, yet strong enough to promptly seat the valve in closing. The proportion of valve area is exceptionally liberal, enabling the cylinder to fill freely at each stroke without volumetric loss or impaired efficiency due to the wire-drawing effect of insufficient valve area.

To meet the objections sometimes offered against a numerous complement of poppet valves, compressors of larger size are also built with mechanically moved intake valves of semi-rotary "Corliss" type placed in the cylinder heads and driven by gear from eccentrics on the main shaft. These positively-moved valves combine exceptional area with short ports and minimum clearance. They open and close without impact, and are therefore free from the hammering and wear incident to poppet valves. These valves are driven by separate eccentrics, which on the duplex steam-driven machines have the advantage of allowing adjustment of the air-valve gear without disturbing the setting of the steam valves.

All air discharge valves are of the poppet type, cup-shaped, pressed from high-grade steel and fitted with light tension springs. These valves have removable seats and guides and are readily accessible for adjustment or repair.

The intercooler provided with two-stage compressors forms part of the base, being located directly under the air cylinders, minimising piping and floor space and rendering the compressor with its intercooler completely self-contained. The intercooler tubes are of brass or charcoal iron expanded into tube steel sheets. Ribs are provided in water heads and baffle plates inserted between tubes, insuring complete circulation of both water and air. The circulation thus obtained, together with the generous amount of cooling surface provided, affords exceptional inter-cooling efficiency. By removing bolts in the outside head the entire nest of tubes may be easily withdrawn for repairs or cleaning. Drains are provided for both air and water spaces.

Full information may be obtained from the manufacturers, the Consolidated Pneumatic Tool Company, at its offices, Palace Chambers, 9, Bridge Street, Westminster, S.W.

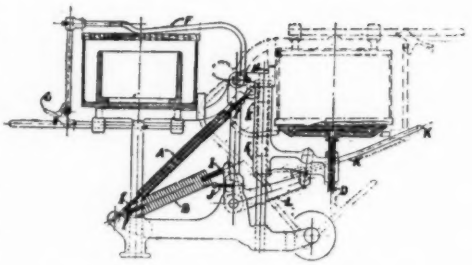
## Rock-Over Drop Moulding Machine.

The first "Pridmore" moulding machine to be designed was of the stripping plate type, admittedly a rapid machine, but its use is limited in a measure to the moulding of patterns from which there are a number of castings required. There are many foundries in which stripping plate machines

cannot be used to advantage on account of there not being a sufficient duplication of castings to warrant the fitting up of the necessary patterns and stripping plates. It is for use in such shops as these that the machine under notice has been designed.

As its name implies, the two main operations of this machine consist of rocking the pattern over and dropping the mould away from the pattern. It can readily be seen that the nature of the rocking over movement is such that facility is practically the only essential feature, but the dropping of the mould away from the pattern is the operation which must be accomplished with the greatest degree of accuracy; the movement of the adjustable table must be absolutely true.

By referring to the detailed view of the machine, it will be seen that the adjustable table consists of two movable draw arms *E*, which travel vertically on two parallel steel uprights, and two self-adjusting flask rests *C*, which are automatically adjustable to crooked bottom boards and to the variation in thickness of bottom boards and depth of flasks. These flask rests are connected with the draw arms by means of screws *D*, which regulate the height of the table according to the depth of flasks to be used. Limit screws *J* are used for limiting the upward movement of the adjustable table. The weight of the flask and mould is perfectly counter-balanced and centrally supported by supporting arms *L* acting in conjunction with flask balance springs *B*, which are capable of rapid adjustment to the weight to be supported. The clamping rod *F*, which can be adjusted to flasks of different widths and depths, is so designed and fitted that the clamping of the bottom board and flask to the rock-over frame is performed at one operation, and in such a manner that it is impossible for either board or flask to shift while the mould is being rocked over. The instantaneous fastening and releasing of this adjustable clamping rod is accomplished by the use of a clamping rod hook *G*. Frame spring balances *A* are used to facilitate the operation of rocking over, and the limit of motion is determined by the coming in contact of frame stops *H*. The tension of both sets of springs can be readily regulated by firmly grasping them with both hands and twisting them forward or backward as may be required, spring adjusting bolts *I* being employed to take up or release the tension. The dropping of the mould away from the pattern is accomplished by the use of a foot lever *K*, and the flask balance springs



DETAILS OF PRIDMORE ROCK OVER DROP MOULDING MACHINE.

*A*. Frame balance-springs.
*B*. Flask balance springs.
*C*. Self-adjusting flask rests.
*D*. Screws for regulating height of table to flasks of different depths.
*E*. Draw arms.
*F*. Adjustable clamping rod.
*G*. Clamping rod hook.
*H*. Frame stops.
*I*. Spring adjusting bolts.
*J*. Limit screws.
*K*. Foot lever.
*L*. Supporting arms.

should be so adjusted that their tension will be sufficient to carry the table upward to its highest position after the pattern has been rocked back, thus obviating the necessity of the operator's stooping down for the flask to set it off on to the floor.

The operation of fitting patterns to this machine is an exceedingly simple one, and it can be performed very rapidly. Either wooden or metal patterns may be used. They should be firmly fastened to the pattern plate, which can be made of either wood or iron. Its upper surface should conform to the parting outline of the pattern, which, in the majority of cases, will be straight. This pattern plate, which should be made with ears and fitted to accommodate the flasks to be used, is attached to the rock-over frame by means of bolts, which pass through four holes that are drilled in the frame.

This manner of attaching the pattern plate to the rock-over frame possesses advantages over spring latches or other inaccurate methods, as the frame is accurately milled on its upper surface, and if the pattern plate is at all uneven, as will frequently be the case, it will be sprung perfectly straight, the bolt holes being located one at each of the four corners of the rock-over frame. The cope part of the pattern, if it is perfectly flat or has sufficient draft to permit of "lifting off," can be made on a stand or dummy. But if the mould cannot be lifted off without breaking, a regular stripping plate machine should be used.

These machines, which are made in nine sizes, are being placed on the market by Messrs. J. W. Jackman & Co., Ltd., of Caxton House, Westminster.

# THE ENGINEERING PRESS.

**In this section is presented every month a list of the more important articles appearing in the Engineering Press and of the leading papers read before the various engineering institutions. Full names, addresses, and published prices of the publications indexed are printed each half-year in the volume index.**

## Civil Engineering.

The New Ferro-Concrete Bridge at Stanford, Worcestershire. *Engineering, 23rd August*, 1907.

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## Sewage.

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Temperature of Incandescent Particles in Luminous Flames. *Journal Gas Lighting, &c., 10th September*, 1907.

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## PRIZE COMPETITIONS FOR ENGINEERS.

In connection with the Second Prize Competition, we regret to have to announce that owing to the elementary and unsatisfactory character of the articles submitted, we have not felt justified in making any award.

Competitors without exception took the first subject, viz.: Live Steam Feed Heating, and confined their efforts to a mere description of existing types of live steam feed heaters. Not one considered the efficiency of the method, or examined the question as to whether it was thermodynamically good or bad. A knowledge of the physical causes which produce an economy when this method of feed heating is adopted is of great importance and interest, and in the hope that competitors will be stimulated to go more carefully into the subject we again offer the prize of £10, under the conditions stated opposite, for the best article. Papers must be sent in on or before December 1st.

### THIRD PRIZE COMPETITION.

The Third Prize Competition relates to Workshop Practice, and is limited to Works Managers, Foremen, and those under their charge, to provide an opportunity of bringing their practical ideas and experiences into print.

Three prizes are offered—one of £5, one of £2, and one of £1—for the best short article describing and illustrating any emergency device or any job which has taxed the ingenuity of the machinist, pattern maker, fitter or foundry operator.

INSTRUCTIONS AND CONDITIONS.

Articles must be written on one side of the paper only, and be signed by the competitor.

Drawings and sketches must be on separate sheets of paper.

A short biographical sketch of the competitor's technical experience should accompany the article.

The right is reserved of publishing the prize article, and also any of the others sent in; but in the case of the latter, payment will be made for the same at our usual scale rates.

The Editor's decision in all matters connected with the competitions shall be final, and binding on all the competitors.

All articles should be addressed to the Editor of THE ENGINEERING REVIEW, 104, High Holborn, London, W.C., and marked on the outside, "Competition," and the same must be received not later than November 1st.